# STRUCTURAL ANALYSIS REPORT

# LASER RANGING RETRO-REFLECTOR

# (300 CORNER)

# APOLLO 15

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## INTRODUCTION

This report consists of the stress analysis performed to substantiate the structural integrity of the LRRR-300 and all of its associated hardware.

All analyses were based on a total package weight of 100 lbs. except for the Plan Grid Analysis Program used on the Array Structures which was based on an LRRR weight of 85 lbs. The LRRR weight, for the CRD, was calculated to be 80.2 lbs.

The ultimate loads used were obtained by multiplying the given limit loads by a factor of 1.5.

In most cases, the margins of safety are high. Low margins of safety are based on conservative assumptions and a more rigorous analysis would show a higher margin.

Items not shown in this report have been investigated and have high margins of safety using defined load factors.

# TABLE OF CONTENTS

## REFERENCES

1. GAC Interface Drawing LID 360-22837, December 3, 1970.

2. Letter No. 9783-951-009 Bendix Internal Memorandum, Force Emission Capability of the Suited Astronaut, dated 21 April, 1970.

3. Report No. 1640, Bendix Corporation Energy Controls Division Structures Manual, revised March 15, 1966.

4. Roark, R. J., "Formulas for Stress and Strain", McGraw-Hill Book Company, Inc. 3rd edition, 1954.

5. Spotts, M.F., "Design of Machine Elements", Prentice-Hall, Inc. 2nd edition, 1955.

6. MIL-HDBK-5A "Metallic Materials and Elements for Aerospace Vehicle Structures", Dept. of Defense, Washington 25, D.C.

7. "Welding Aluminum", American Welding Society, 1967.

8. ATM-871, Structural/Dynamics Analysis Report, Apollo 14 LRRR, May 15, 1970.

9. Report No. BSR-2910, Bendix Corporation Aerospace Systems Division, Plane Grid Analysis by Direct Element Method, Program No. 0313 dated May 1970.

10. "Handbook of Mechanical Spring Design", Associated Spring Corporation, 1964.

## SUMMARY OF CONDITIONS

The following conditions were considered in determining the structural integrity of the LRRR-300:

| CONDITION NO. | DESCRIPTION |
|---|---|
| 1. | Twenty G's limit load (30 G's ultimate) acting independently along each major axis in the stowed position during flight. |
| 2. | Force emission capability of the suited astronaut of 30 pounds limit (45 pounds ultimate) in any direction. |
| 3. | Two G's ultimate load in the un-deployed and deployed configuration during earth handling. |

FINAL ANALYSIS LRRR-300
LARGE ARRAY INPUT DATA PLANE GRID ANALYSIS PROGRAM (1)

LOADING CONDITION : REF. DYNAMICS LOADS IN DYNAMICS ANALYSIS REPORT ATM-936

CONTROL DATA :

| | |
|---|---|
| NUMBER OF NODES | NN = 40 |
| NUMBER OF MEMBERS | NM = 48 |
| NUMBER OF RESTRAINED NODES | NRN = 4 |
| NUMBER OF RESTRAINTS | NR = 4 |
| NUMBER OF LOADING CONDITIONS | NLC = 1 |
| NUMBER OF PROBLEMS | NSC = 1 |

REFERENCE DATA :

YOUNG'S MODULUS, E : $10^7$ PSI
POISSON'S RATIO, $\nu$ : .30

SUPPORT CONDITIONS :

| NODE | $I_1$ | $I_2$ | $I_3$ | $X_1$ | $X_2$ | $X_3$ |
|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 5 | 0 | 0 | 1 | 0 | 0 | 0 |
| 34 | 0 | 0 | 1 | 0 | 0 | 0 |
| 40 | 0 | 0 | 1 | 0 | 0 | 0 |

MEAN SECTION PROPERTIES (2)

BEAMS ALONG X-X DIRECTION

$I = .22565 \text{ IN}^4/\text{IN}$, $J = .002804 \text{ IN}^4/\text{IN}$
$C = 1.23180 \text{ IN}$, $Q = .025$

BEAMS ALONG Y-Y DIRECTION

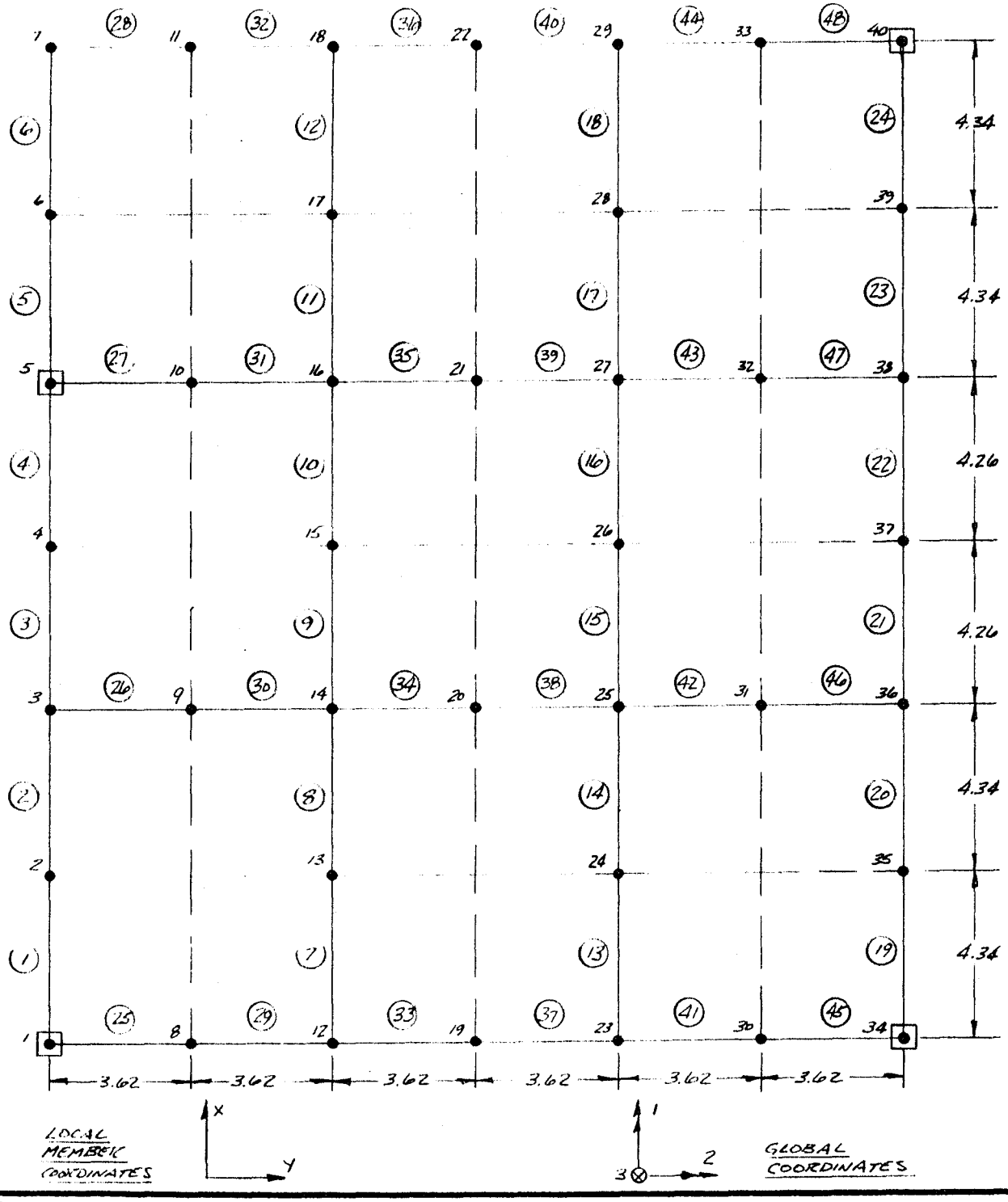
$I = .23969 \text{ IN}^4/\text{IN}$, $J = .0027974 \text{ IN}^4/\text{IN}$
$C = 1.253 \text{ IN}$, $Q = .025$

(2) SECTION PROPERTY CALCULATIONS OMITTED TO SIMPLIFY REPORT
(1) REF. NO. 9

FINAL ANALYSIS LRRR-500

LARGE ARRAY - NODAL POINT AND MEMBER NUMBER ARRANGEMENT

PLANE GRID ANALYSIS PROGRAM - REF. No. 9



FINAL ANALYSIS LRRR-300
LARGE ARRAY SECTIONAL PROPERTIES (1)
PLANE GRID ANALYSIS PROGRAM (2)

| MEMBER | NI | NJ | X | Y | I | J |
|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 4.34 | 0 | .8677 | .0101 |
| 2 | 2 | 3 | 4.34 | | | |
| 3 | 3 | 4 | 4.26 | | | |
| 4 | 4 | 5 | 4.26 | | | |
| 5 | 5 | 6 | 4.34 | | | |
| 6 | 6 | 7 | | | .8677 | .0101 |
| 7 | 12 | 13 | | | 1.7354 | .0203 |
| 8 | 13 | 14 | 4.34 | | | |
| 9 | 14 | 15 | 4.26 | | | |
| 10 | 15 | 16 | 4.26 | | | |
| 11 | 16 | 17 | 4.34 | | | |
| 12 | 17 | 18 | | | | |
| 13 | 23 | 24 | | | | |
| 14 | 24 | 25 | 4.34 | | | |
| 15 | 25 | 26 | 4.26 | | | |
| 16 | 26 | 27 | 4.26 | | | |
| 17 | 27 | 28 | 4.34 | | | |
| 18 | 28 | 29 | | | 1.7354 | .0203 |
| 19 | 34 | 35 | | | .8677 | .0101 |
| 20 | 35 | 36 | 4.34 | | | |
| 21 | 36 | 37 | 4.26 | | | |
| 22 | 37 | 38 | 4.26 | | | |
| 23 | 38 | 39 | 4.34 | | | |
| 24 | 39 | 40 | 4.34 | 0 | .8677 | .0101 |

(2) REF. No. 9
(1) REF. DIAGRAM, PAGE 2 & SECTION PROPERTIES, PAGE 1

FINAL ANALYSIS LRRR-300
LARGE ARRAY SECTIONAL PROPERTIES (1) (CONT'D)
PLANE GRID ANALYSIS PROGRAM (2)

| MEMBER | NI | NJ | X | Y | I | J |
|---|---|---|---|---|---|---|
| 25 | 1 | 8 | 0 | 3.62 | .9793 | .0122 |
| 26 | 3 | 9 | | | 1.9406 | .0241 |
| 27 | 5 | 10 | | | 1.9406 | .0241 |
| 28 | 7 | 11 | | | .9793 | .0122 |
| 29 | 8 | 12 | | | .9793 | .0122 |
| 30 | 9 | 14 | | | 1.9406 | .0241 |
| 31 | 10 | 16 | | | 1.9406 | .0241 |
| 32 | 11 | 18 | | | .9793 | .0122 |
| 33 | 12 | 19 | | | .9793 | .0122 |
| 34 | 14 | 20 | | | 1.9406 | .0241 |
| 35 | 16 | 21 | | | 1.9406 | .0241 |
| 36 | 18 | 22 | | | .9793 | .0122 |
| 37 | 19 | 23 | | | .9793 | .0122 |
| 38 | 20 | 25 | | | 1.9406 | .0241 |
| 39 | 21 | 27 | | | 1.9406 | .0241 |
| 40 | 22 | 29 | | | .9793 | .0122 |
| 41 | 23 | 30 | | | .9793 | .0122 |
| 42 | 25 | 31 | | | 1.9406 | .0241 |
| 43 | 27 | 32 | | | 1.9406 | .0241 |
| 44 | 29 | 33 | | | .9793 | .0122 |
| 45 | 30 | 34 | | | .9793 | .0122 |
| 46 | 31 | 36 | | | 1.9406 | .0241 |
| 47 | 32 | 38 | | | 1.9406 | .0241 |
| 48 | 33 | 40 | 0 | 3.62 | .9793 | .0122 |

(2) REF. NO. 9
(1) REF. DIAGRAM, PAGE 2 & SECTION PROPERTIES, PAGE 1

FINAL ANALYSIS LRRR-300
LARGE ARRAY MEMBER MOMENTS AND STRESSES (1)
PLANE GRID ANALYSIS PROGRAM (2)

| MEMBER | END BENDING MOMENTS $F_1$ | $F_2$ | TORSIONAL MOMENT $F_3$ | END BENDING STRESSES $S_1$ | $S_2$ | TORSIONAL STRESS $S_3$ |
|---|---|---|---|---|---|---|
| 1 | -1.92 | -374.4 | -2.12 | -2.72 | -531.7 | -2.09 |
| 2 | 374.5 | -422.1 | -2.12 | 531.6 | -599.4 | -2.09 |
| 3 | 421.6 | 99.0 | -.12 | 598.5 | 140.4 | -.11 |
| 4 | -99.0 | 1057.2 | -.12 | -140.4 | 1500.6 | -.11 |
| 5 | -1059.9 | 527.7 | -2.71 | -1504.5 | 749.1 | -2.68 |
| 6 | -527.7 | -4.44 | -2.71 | -749.1 | -6.30 | -2.68 |
| 7 | 6.30 | -157.4 | 1.25 | 4.47 | -111.9 | .62 |
| 8 | 157.6 | -16.8 | 1.25 | 111.9 | -11.94 | .62 |
| 9 | 21.9 | 33.3 | -.21 | 15.6 | 23.6 | -.10 |
| 10 | -33.2 | 324.3 | -.21 | -23.6 | 230.2 | -.10 |
| 11 | -326.7 | 48.9 | -5.92 | -231.9 | 34.8 | -2.92 |
| 12 | -49.0 | -1.18 | -5.92 | -34.8 | -.84 | -2.92 |
| 13 | 6.84 | -774.3 | 11.28 | 4.86 | -549.6 | 5.57 |
| 14 | 774.3 | -1260.0 | 11.28 | 549.6 | -894.6 | 5.57 |
| 15 | 1267.5 | -1507.2 | .48 | 899.7 | -1069.8 | .24 |
| 16 | 1507.2 | -1480.8 | .48 | 1069.8 | -1050.9 | .24 |
| 17 | 1476.9 | -843.6 | -10.04 | 1048.2 | -598.8 | -4.96 |
| 18 | 843.9 | -3.36 | -10.04 | 599.1 | -2.40 | -4.96 |
| 19 | -11.4 | -1199.7 | 9.13 | -16.2 | -1703.4 | 9.02 |
| 20 | 1199.4 | -2188.5 | 9.13 | 1702.8 | -3106.8 | 9.02 |
| 21 | 2176.2 | -2700.0 | .63 | 3089.4 | -3833.1 | .63 |
| 22 | 2700.0 | -1993.8 | .63 | 3833.1 | -2830.5 | .63 |
| 23 | 2003.4 | -1140.3 | -6.75 | 2843.7 | -1619.1 | -6.66 |
| 24 | 1140.9 | 9.11 | -6.75 | 1619.7 | 12.9 | -6.66 |

THE STRESSES TABULATED ON THIS PAGE AND THE FOLLOWING PAGE ARE THE PEAK STRESSES DEVELOPED IN THE ARRAY. IN COMPARING THESE STRESS LEVELS WITH THE DESIGN STRENGTH PROPERTIES OF THE ARRAY MAT'L. (3) IT IS OBVIOUS THE ARRAY HAS ADEQUATE STRUCTURAL STRENGTH.

(2) REF. NO. 9
(3) AL. ALLOY 6061-T6 PER QQ-A-250/11
(1) MOMENTS IN IN-lbs & STRESSES IN PSI - FROM COMPUTER OUTPUT

FINAL ANALYSIS LRRR-300
LARGE ARRAY MEMBER MOMENTS AND STRESSES (1) (CONT'D)
PLANE GRID ANALYSIS PROGRAM (2)

| MEMBER | END BENDING MOMENTS F1 | F2 | TORSIONAL MOMENT F3 | END BENDING STRESSES S1 | S2 | TORSIONAL STRESS S3 |
|---|---|---|---|---|---|---|
| 25 | -2.31 | -1252.2 | 1.91 | -2.96 | -1602.0 | 1.57 |
| 26 | 1.90 | -484.2 | .59 | 1.23 | -312.6 | .24 |
| 27 | -2.60 | -439.8 | 2.63 | -1.68 | -284.1 | 1.09 |
| 28 | 2.74 | -273.6 | 4.40 | 3.51 | -350.1 | 3.61 |
| 29 | 1251.6 | -1620.9 | 1.91 | 1601.7 | -2073.9 | 1.57 |
| 30 | 483.9 | -634.5 | .59 | 312.3 | -409.8 | .24 |
| 31 | 439.5 | -701.1 | 2.63 | 283.8 | -452.7 | 1.09 |
| 32 | 273.6 | -544.5 | 4.40 | 350.1 | -696.9 | 3.61 |
| 33 | 1621.8 | -1864.5 | -4.29 | 2075.1 | -2385.6 | -3.53 |
| 34 | 632.4 | -713.1 | -4.53 | 408.3 | -460.5 | -1.88 |
| 35 | 695.1 | -478.2 | 5.11 | 448.8 | -308.7 | 2.12 |
| 36 | 550.5 | -863.1 | 5.49 | 704.4 | -1104.3 | 4.51 |
| 37 | 1864.5 | -1962.9 | -4.29 | 2385.6 | -2511.6 | -3.53 |
| 38 | 712.8 | -455.1 | -4.53 | 460.2 | -293.7 | -1.88 |
| 39 | 477.6 | -54.6 | 5.11 | 308.4 | -35.4 | 2.12 |
| 40 | 863.1 | -1068.1 | 5.49 | 1104.0 | -1366.8 | 4.51 |
| 41 | 1974.3 | -1432.2 | -11.19 | 2526.3 | -1832.7 | -9.18 |
| 42 | 444.3 | -387.9 | -12.0 | 286.8 | -250.5 | -4.97 |
| 43 | 44.0 | -126.6 | 9.03 | 28.4 | -81.6 | 3.75 |
| 44 | 1078.2 | -582.3 | 8.91 | 1379.7 | -744.9 | 7.32 |
| 45 | 1432.8 | 9.30 | -11.19 | 1833.0 | 11.9 | -9.18 |
| 46 | 387.6 | -9.00 | -12.0 | 250.2 | -5.76 | -4.97 |
| 47 | 126.3 | -7.59 | 9.03 | 81.6 | -4.89 | 3.75 |
| 48 | 582.3 | 6.81 | 8.91 | 745.2 | 8.70 | 7.32 |

(2) REF NO. 9
(1) MOMENTS IN IN-LBS & STRESSES IN PSI - FROM COMPUTER OUTPUT, SEE NOTE PAGE 5

FINAL ANALYSIS LRRR-300

SMALL ARRAY · INPUT DATA PLANE GRID ANALYSIS PROGRAM (1)

LOADING CONDITION: REF. DYNAMICS LOADS IN DYNAMICS ANALYSIS REPORT ATM-936

CONTROL DATA:

| | |
|---|---|
| NUMBER OF NODES | NN = 21 |
| NUMBER OF MEMBERS | NM = 32 |
| NUMBER OF RESTRAINED NODES | NRN = 4 |
| NUMBER OF RESTRAINTS | NR = 4 |
| NUMBER OF LOADING CONDITIONS | NLC = 1 |
| NUMBER OF PROBLEMS | NSC = 1 |

REFERENCE DATA:

YOUNG'S MODULUS, E : $10^7$ PSI
POISSON'S RATIO, V : .30

SUPPORT CONDITIONS:

| NODE | $I_1$ | $I_2$ | $I_3$ | $X_1$ | $X_2$ | $X_3$ |
|---|---|---|---|---|---|---|
| 3 | 0 | 0 | 1 | 0 | 0 | 0 |
| 4 | 0 | 0 | 1 | 0 | 0 | 0 |
| 16 | 0 | 0 | 1 | 0 | 0 | 0 |
| 21 | 0 | 0 | 1 | 0 | 0 | 0 |

MEAN SECTIONAL PROPERTIES: (2)

BEAMS ALONG THE X-X DIRECTION

$I = .22208\ IN^4/IN$, $J = .0029674\ IN^4/IN$
$C = 1.22486\ IN$, $Q = .025$

BEAMS ALONG THE Y-Y DIRECTION

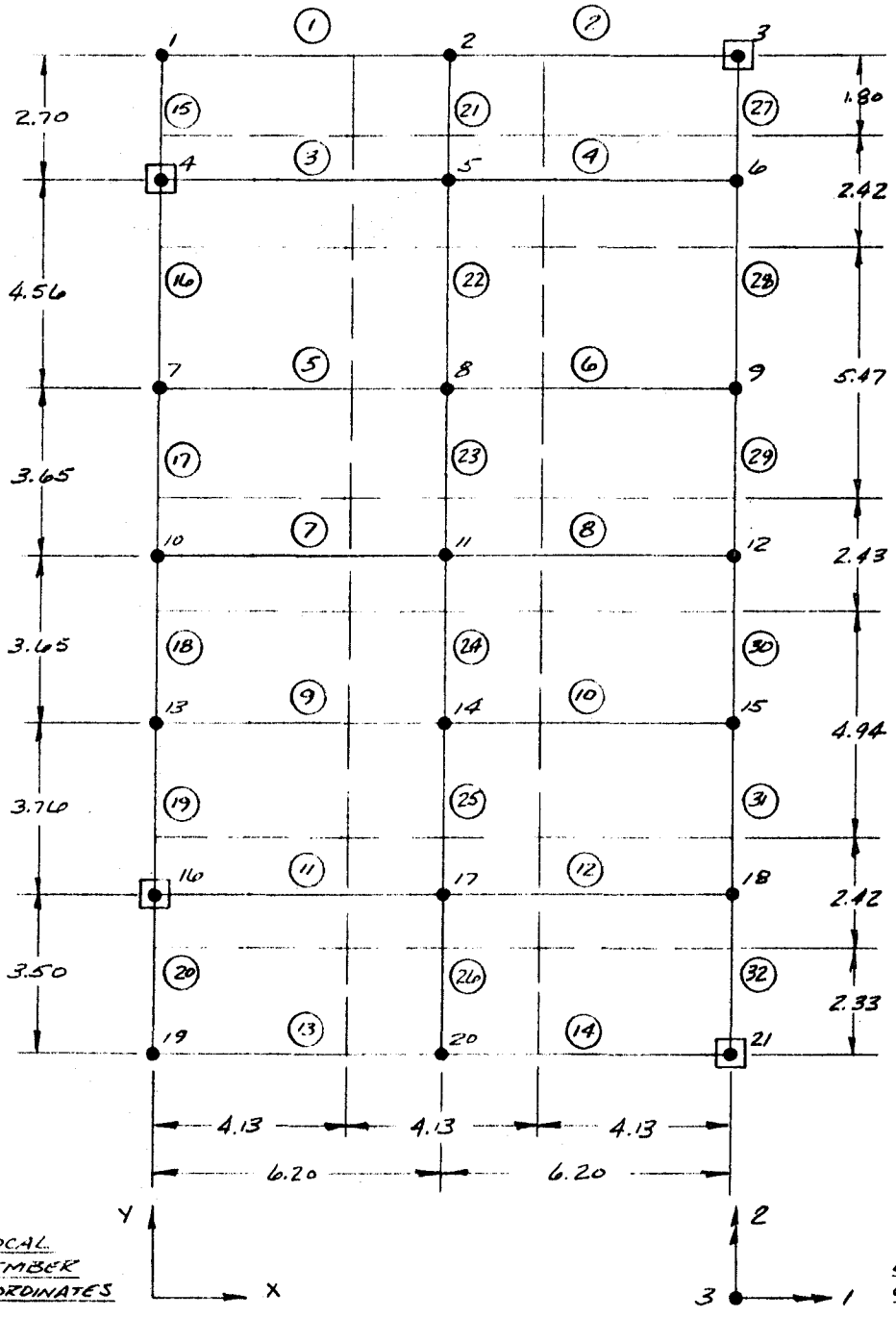
$I = .21427\ IN^4/IN$, $J = .0027828\ IN^4/IN$
$C = 1.22502\ IN$, $Q = .025$

(2) SECTION PROPERTY CALCULATIONS OMITTED TO SIMPLIFY REPORT
(1) REF. NO. 9

FINAL ANALYSIS - LRRR-300

SMALL ARRAY - NODAL POINT AND MEMBER NUMBER ARRANGEMENT

PLANE GRID ANALYSIS PROGRAM (1)




(1) KEY NO. 9

FINAL ANALYSIS LRRR-300

SMALL ARRAY SECTIONAL PROPERTIES (1) PLANE GRID ANALYSIS PROGRAM (2)

| MEMBER | NI | NJ | X | Y | I | J |
|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 6.20 | 0 | .3997 | .0054 |
| 2 | 2 | 3 | | | .3997 | .0054 |
| 3 | 4 | 5 | | | .5374 | .0073 |
| 4 | 5 | 6 | | | .5374 | .0073 |
| 5 | 7 | 8 | | | 1.2148 | .0162 |
| 6 | 8 | 9 | | | 1.2148 | .0162 |
| 7 | 10 | 11 | | | .5374 | .0072 |
| 8 | 11 | 12 | | | .5374 | .0072 |
| 9 | 13 | 14 | | | 1.0971 | .0147 |
| 10 | 14 | 15 | | | 1.0971 | .0147 |
| 11 | 16 | 17 | | | .5374 | .0072 |
| 12 | 17 | 18 | | | .5374 | .0072 |
| 13 | 19 | 20 | | | .5175 | .0069 |
| 14 | 20 | 21 | 6.20 | 0 | .5175 | .0069 |
| 15 | 1 | 4 | 0 | 2.70 | .7799 | .0101 |
| 16 | 4 | 7 | | 4.56 | | |
| 17 | 7 | 10 | | 3.65 | | |
| 18 | 10 | 13 | | 3.65 | | |
| 19 | 13 | 16 | | 3.76 | | |
| 20 | 16 | 19 | | 3.50 | | |
| 21 | 2 | 5 | | 2.70 | | |
| 22 | 5 | 8 | | 4.56 | | |
| 23 | 8 | 11 | | 3.65 | | |
| 24 | 11 | 14 | | 3.65 | | |
| 25 | 14 | 17 | | 3.76 | | |
| 26 | 17 | 20 | | 3.50 | | |
| 27 | 3 | 6 | | 2.70 | | |
| 28 | 6 | 9 | | 4.56 | | |
| 29 | 9 | 12 | | 3.65 | | |
| 30 | 12 | 15 | | 3.65 | | |
| 31 | 15 | 18 | | 3.76 | | |
| 32 | 18 | 21 | 0 | 3.50 | .7799 | .0101 |

(1) REF. DIAGRAM, PAGE 8 & SECTION PROPERTIES, PAGE 7 (2) REF. NO. 9

FINAL ANALYSIS LRRR-300

SMALL ARRAY MOMENTS AND STRESSES (1) (3) PLANE GRID ANALYSIS PROGRAM (2)

| MEMBER | END BENDING MOMENTS F1 | F2 | TORSIONAL MOMENT F3 | END BENDING STRESSES S1 | S2 | TORSIONAL STRESS S3 |
|---|---|---|---|---|---|---|
| 1 | -1.64 | 170.4 | -1.05 | -5.04 | 522.2 | -4.83 |
| 2 | -172.8 | -3.09 | -1.61 | -529.5 | -9.48 | -7.41 |
| 3 | .45 | 131.1 | -1.27 | 1.04 | 298.8 | -4.35 |
| 4 | -130.3 | 1.05 | -1.86 | -297.1 | 2.40 | -6.36 |
| 5 | .90 | 73.1 | -1.29 | .91 | 73.8 | -1.98 |
| 6 | -72.0 | 1.27 | -2.05 | -72.6 | 1.29 | -3.15 |
| 7 | .53 | -14.6 | -.03 | 1.22 | -33.2 | -.10 |
| 8 | 15.6 | 1.51 | -.05 | 35.5 | 3.45 | -.17 |
| 9 | .88 | 57.1 | 1.07 | .99 | 63.9 | 1.83 |
| 10 | -56.0 | 1.31 | 1.78 | -62.5 | 1.47 | 3.02 |
| 11 | .65 | 111.1 | 1.21 | 1.50 | 253.2 | 4.20 |
| 12 | -110.2 | 1.12 | 1.74 | -251.1 | 2.55 | 6.03 |
| 13 | -1.74 | 219.8 | 1.44 | -4.12 | 520.2 | 5.19 |
| 14 | -222.2 | -3.08 | 2.10 | -525.9 | -7.29 | 7.56 |
| 15 | -1.04 | -82.5 | 1.64 | -1.65 | -129.6 | 4.05 |
| 16 | 81.3 | 135.9 | 1.19 | 127.7 | 213.2 | 2.94 |
| 17 | -137.1 | 261.2 | .30 | -215.3 | 410.4 | .75 |
| 18 | -261.2 | 85.2 | -.23 | -410.4 | 133.8 | -.57 |
| 19 | -84.1 | -137.4 | -1.09 | -132.0 | -215.7 | -2.70 |
| 20 | 138.6 | 1.44 | -1.74 | 217.7 | 2.25 | -4.29 |
| 21 | -.54 | 79.8 | 2.38 | -.86 | 125.1 | 5.88 |
| 22 | -80.4 | 432.2 | 1.62 | -126.1 | 678.9 | 3.99 |
| 23 | -432.9 | 422.4 | .56 | -680.1 | 663.3 | 1.38 |
| 24 | -422.4 | 390.9 | -.46 | -663.3 | 613.8 | -1.14 |
| 25 | -390.1 | 115.2 | -1.53 | -612.9 | 180.9 | -3.78 |
| 26 | -114.6 | .65 | -2.42 | -180.2 | 1.02 | -5.97 |
| 27 | 1.63 | 430.8 | 3.09 | 2.55 | 676.5 | 7.62 |
| 28 | -428.7 | 705.0 | 2.05 | -673.5 | 1107.1 | 5.04 |
| 29 | -702.9 | 876.3 | .81 | -1103.7 | 1376.4 | 1.98 |
| 30 | -876.3 | 710.1 | -.69 | -1376.3 | 1115.4 | -1.70 |
| 31 | -711.9 | 503.1 | -1.97 | -1118.1 | 789.9 | -4.86 |
| 32 | -504.6 | -2.13 | -3.07 | -792.9 | -3.33 | -7.59 |

(3) SEE NOTE, PAGE 5

(1) MOMENTS IN IN-LBS & STRESSES IN PSI - FROM COMPUTER OUTPUT (2) REF. NO. 9

FINAL ANALYSIS LRRR-300

BOLT PATTERN - LEFT & RIGHT FORWARD INTERFACE BRACKETS

ANALYSIS TO LARGE ARRAY DWG. 2347230-231

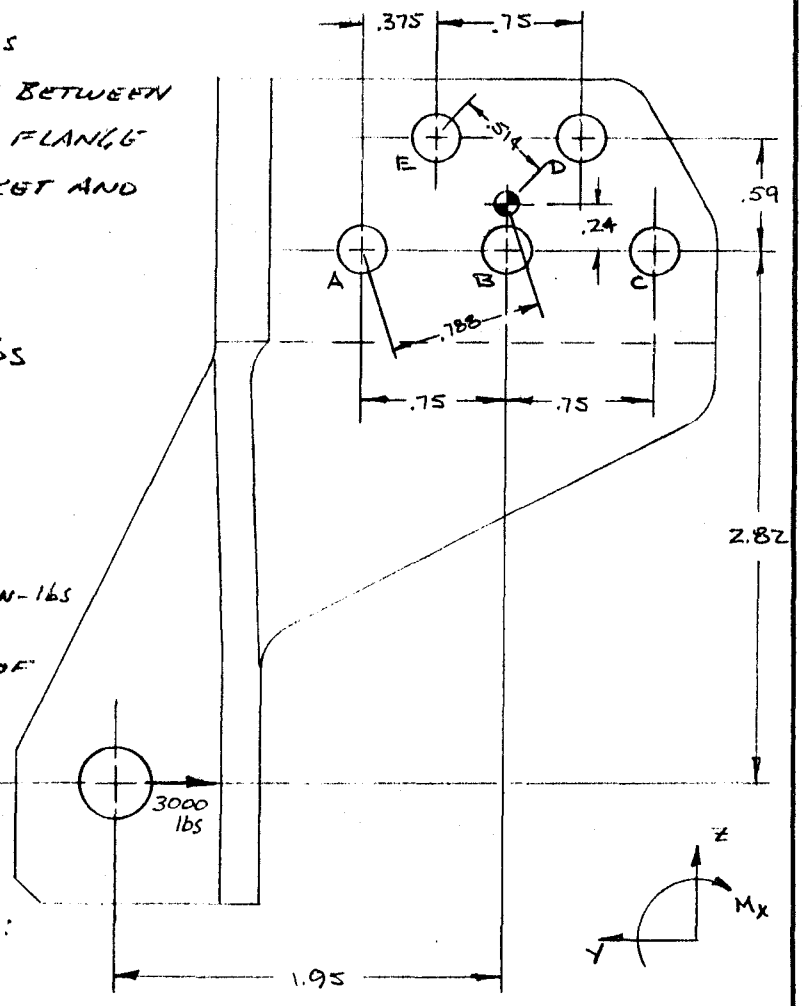
LOADS COND. 1

ASSUMPTIONS:

(1) 1. BRACKET LOAD = 3000 lbs

2. 75-25 LOAD DISTRIBUTION BETWEEN BOLT PATTERNS OF EACH FLANGE

3. FRICTION BETWEEN BRACKET AND ARRAY NEGLECTED




BOLT PATTERN LOAD:

$P_{B.P.} = .75\ P_{BKT} = 2250$ lbs

DIRECT FORCE ON BOLTS:

$F = \frac{2250}{5} = 450$ lbs

BOLT PATTERN MOMENT:

$M_{B.P.} = 3.06(2250) = 6880$ in-lbs

CONSTANT OF PROPORTIONALITY OF BOLT PATTERN, K:

(2) $K = \frac{6880}{2(.788)^2 + 2(.514)^2 + (.24)^2} = 3760$

MOMENT FORCE ON BOLT (A):

(2) $F_A = K r_A = 3760(.788) = 2960$ lbs

TOTAL FORCE AT BOLT (A):

(3) $F_{TOT_A} = F + F_A = 3410$ lbs

BOLT DESIGNATION

NAS 6704 U4 BOLT SINGLE SHEAR STRENGTH = 4650 lbs

BOLT MARGIN OF SAFETY

$M.S. = \frac{4650}{3410} - 1 = +.36$

(3) CONSERVATIVELY ASSUME LOADS ACTING IN LINE

(2) REF. NO. 5, PAGE 239

(1) BRACKET ASSUMED TO TAKE TOTAL LR$^3$ FORCE

FINAL ANALYSIS LRRR-300

RETRO REFLECTOR STRUCTURE (LARGE ARRAY) DWG 2347205

BEARING CHECK - INTERFACE BRACKET ATTACH BOLTS AGAINST ARRAY

LOADS ON ARRAY

BRACKET LOAD AT BOLT (A):

(1) $F_{TOT_A} = 3410$

BEARING PROPERTIES

BOLT DIA = .250
ARRAY WALL THICKNESS = .156
$A_{br} = Dt = .039$

BEARING STRESSES MAT'L: 6061-T6 AL. ALLOY $F_{tu} = 42$ KSI

$F_{bru} = 88$ KSI $\qquad f_{br} = \frac{3410}{.039} = 87.5$ KSI

(2) $M.S. = \frac{F_{bru}}{f_{br}} - 1 = \underline{+.00}$

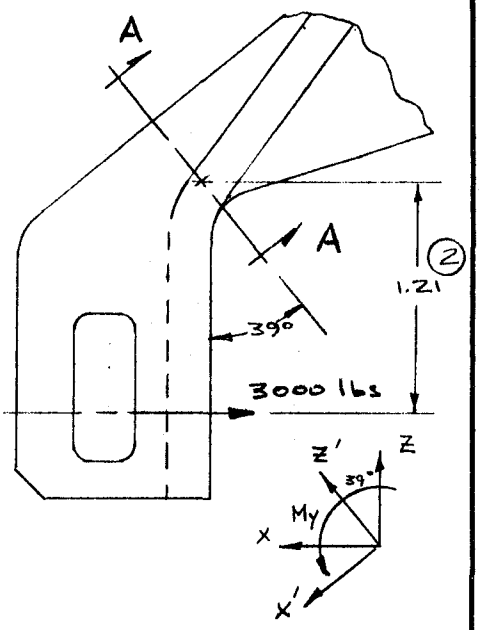
(2) BEARING FACTOR NEGLECTED DUE TO CONSERVATISMS IN THE ANALYSIS
(1) REF PAGE 11

FINAL ANALYSIS LRRR-300

(3) BRACKET, INTERFACE - LEFT FORWARD DWG. 2347230

SECTION A-A

LOADS & MOMENTS COND. 1

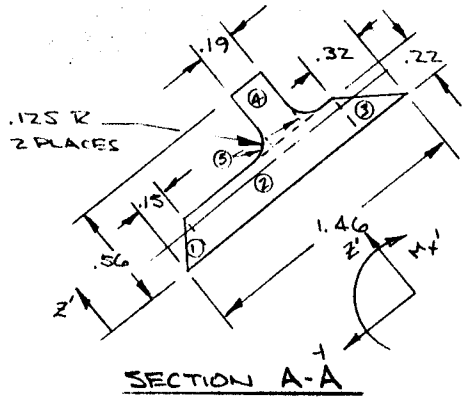



(1) MOUNTING PIN LOAD = 3000 lbs

COMPRESSION = 3000 COS 39° = 2330 lbs

SHEAR = 3000 SIN 39° = 1890 lbs

B.M. = 1.21 (3000) = 3630 IN-lbs




SECTION PROPERTIES SECTION A-A

| SEG | A | Z' | $A_{Z'}$ | $I_{o_{Z'}}$ | $d_{Z'}$ | $Ad_{Z'}^2$ |
|---|---|---|---|---|---|---|
| 1 | .0165 | .073 | .0012 | .00004 | .087 | .00012 |
| 2 | .2178 | .110 | .0240 | .00087 | .050 | .00054 |
| 3 | .0352 | .073 | .0026 | .00009 | .087 | .00027 |
| 4 | .0646 | .340 | .0252 | .00062 | .230 | .00342 |
| 5 | .0067 | .248 | .0017 | — | .088 | .00005 |
| | .3408 | | .0547 | .00162 | | .0044 |

$$\bar{Z}' = \frac{\Sigma A Z'}{A} = .16$$

$$I_{Z'} = I_{o_{Z'}} + Ad_{Z'}^2 = .00602 \qquad I_{Z'/C} = .0376$$

$$Q_{Z'} = \frac{1.12\,(.16)^2}{2} + \frac{.11(.16).107}{2} + \frac{.23\,(.16).107}{2} = .01775$$

$$K_{Z'} = 2Q_{Z'}/I_{Z'/C} = .92 \quad \text{USE } 1.0$$

(3) THIS ANALYSIS COVERS THE RIGHT FORWARD INTERFACE BRACKET ALSO.

(1) REF. PAGE 11 (2) ASSUME MOUNTING PIN SHIFTED TO BOTTOM OF SLOT

FINAL ANALYSIS LRRR-300

BRACKET, INTERFACE - LEFT FORWARD

SECTION A-A (CONT'D)

STRESSES MAT'L: TITANIUM 6AL-4V COND A

$F_{tu} = 130$ KSI

$F_{bu} = F_{tu} = 130$ KSI $\quad f_b = \frac{3630}{.0376} = 96.5$ KSI $\quad R_b = .743$

$F_{cy} = 126$ KSI $\quad f_c = \frac{2330}{.3408} = 6.84$ KSI $\quad R_c = .054$

$F_{su} = 80$ KSI $\quad f_s = \frac{1890}{.3408} = 5.55$ KSI $\quad R_s = .069$

$$U = \left[ (R_b + R_c)^2 + R_s^2 \right]^{1/2} = .80$$

$$M.S. = \frac{1}{U} - 1 = \underline{+.25}$$

FINAL ANALYSIS LRRR-300

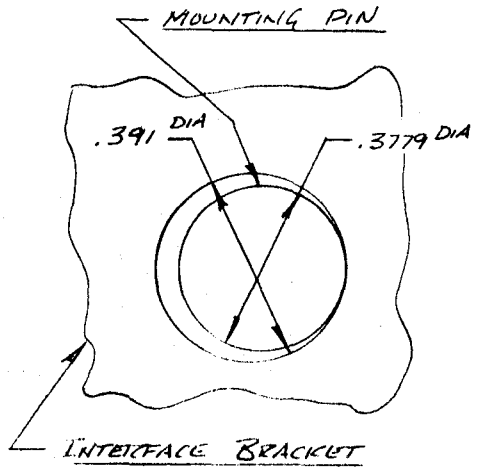
③ BRACKET, INTERFACE - LEFT FORWARD DWG. 2347230

BEARING CHECK - MOUNTING PINS AGAINST BRACKET

LOADS ON BRACKET

① MOUNTING PIN LOAD = 3000 lbs

$$p = \frac{3000}{.12} = 25000 \text{ lbs/in}$$




BEARING PROPERTIES

BRACKET HOLE DIA = .391 = $D_1$
MOUNTING PIN DIA = .3779 = $D_2$
EFFECTIVE BEARING LENGTH = .12

BRACKET MAT'L:
TITANIUM 6AL-4V
$F_{cy}$ = 126 KSI
$E_1 = 16 \times 10^6$ PSI
$\nu_1$ = .32

MOUNTING PIN MAT'L:
STEEL
$E_2 = 29 \times 10^6$ PSI
$\nu_2$ = .32

STRESSES

$F_{cy}$ = 126 KSI

② $$f_c = .798 \left( \frac{p \frac{D_1 - D_2}{D_1 D_2}}{\left[ \frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2} \right]} \right)^{1/2} = 126 \text{ KSI}$$

$$M.S. = \frac{F_{cy}}{f_c} - 1 = \underline{+0}$$

③ THIS ANALYSIS COVERS THE RIGHT FORWARD INTERFACE BRACKET ALSO.
② REF. NO. 4, TABLE XIV, CASE 6
① REF. PAGE 11

FINAL ANALYSIS LRRR-300

BOLT PATTERN ANALYSIS - LEFT REAR INTERFACE BRACKET TO LARGE ARRAY DWG. 2347232 COND. 1

LOADS

ASSUMPTIONS:

REF. PAGE 11

BOLT PATTERN LOAD:

$P_{B.P.} = .75\ P_{BKT}$ (1)

$= .75\ (3000) = 2250$ lbs

DIRECT FORCE ON BOLTS:

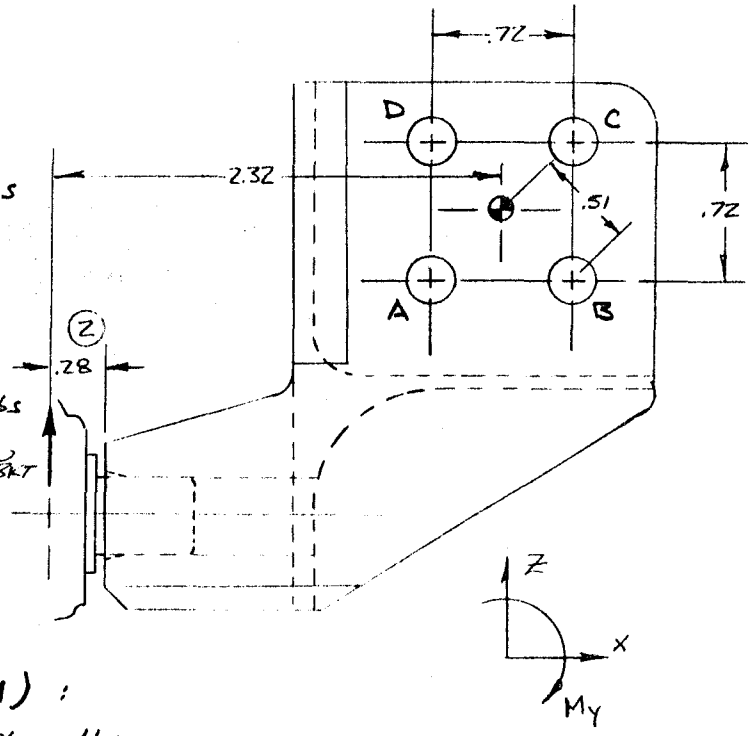
$F = \frac{2250}{4} = 563$ lbs

BOLT PATTERN MOMENT:

$M_{B.P.} = 2.32\ (2250) = 5220$ in-lbs

CONSTANT OF PROPORTIONALITY OF BOLT PATTERN, K:

(3) $K = \frac{5220}{4\ (.51)^2} = 5020$




MOMENT FORCE AT BOLT (A):

(3) $F_A = Kr_A = 5020\ (.51) = 2560$ lbs

TOTAL FORCE AT BOLT (A):

(4) $F_{TOT_A} = F + F_A = 3123$ lbs

BOLT DESIGNATION

NAS 6704 U4 BOLT SINGLE SHEAR STRENGTH = 4650 lbs

MARGIN OF SAFETY

$M.S. = \frac{4650}{3123} - 1 = +.48$

(4) CONSERVATIVELY ASSUME LOADS ACTING IN LINE.
(3) REF. NO. 5, PAGE 239
(2) ASSUMED POINT OF LOAD APPLICATION.
(1) BRACKET ASSUMED TO TAKE TOTAL LR³ FORCE

FINAL ANALYSIS LRRR-300

BRACKET, INTERFACE - LEFT REAR DWG. 2347232

SOCKET ANALYSIS (1)

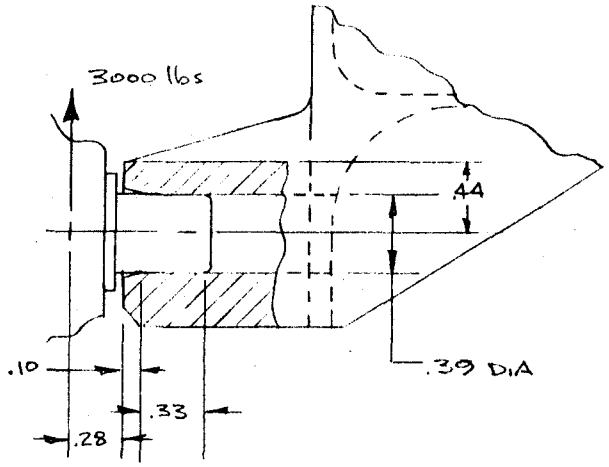
SOCKET LOADS

(2) $P_{BRACKET} = 3000$ lbs

$$V_1 = \frac{P_{BKT}(d + L/2)}{L - L_{br}} + \frac{P_{BKT}}{2}$$

$$= \frac{3000(.445)}{.238} + \frac{3000}{2}$$

$$= 7100 \text{ lbs}$$




SOCKET PROPERTIES

$D = .39$ $\quad L/D = .845$

$L = .33$ $\quad L_{br}/L = .28$ $\quad L_{br} = .092$ $\quad e_{ty} = \frac{F_{ty}}{E} + .002 = .0095$

$t = t_1 = .249$

$a = .44$ $\quad a/D = 1.13$ $\quad$ (3) $C_y = 1.60$

SOCKET ASSEMBLIES MAT'L: TITANIUM 6AL-4V COND A

$F_{tu} = 130$ KSI
$F_{ty} = 120$ KSI
$E = 16 \times 10^6$ PSI

YIELD CHECK

$$V_y = \left[\frac{D/2 + t_1}{a}\right] C_y D L_{br} E e_{ty}$$

$$= \left[\frac{.195 + .249}{.44}\right] 1.60(.39).092(16 \times 10^6).0095$$

$$= 8640 \text{ lbs}$$

$$M.S. = \frac{V_y}{1.15 V_1} - 1 = \underline{+.06}$$

(4)

(4) FITTING FACTOR
(3) EXTRAPOLATED
(2) REF. PAGE 11
(1) REF. NO. 3, SECTION 2.60

FINAL ANALYSIS LRRR-300

BRACKET, INTERFACE - LEFT REAR DWG. 2347232

BEARING CHECK ATTACH BOLTS AGAINST BRACKET

LOAD

BRACKET LOAD AT BOLT (A):

(1) $F_{TOT_A} = 3123$ lbs

BEARING PROPERTIES

BOLT DIA = .25

BRACKET WALL THICKNESS = .12

$A_{br} = Dt = .03$

BEARING STRESSES MAT'L: TITANIUM 6AL-4V COND. A

$F_{bry} = 174$ KSI $\quad f_{br} = \frac{3123}{.03} = 104.2$

$$M.S. = \frac{F_{bry}}{(2)\ 1.5\ f_{br}} - 1 = +.11$$

(2) BEARING FACTOR.

(1) REF PAGE 16

FINAL ANALYSIS LRRR-300

BOLT PATTERN ANALYSIS — RIGHT REAR INTERFACE BRACKET TO LARGE ARRAY — DWG. 2347233

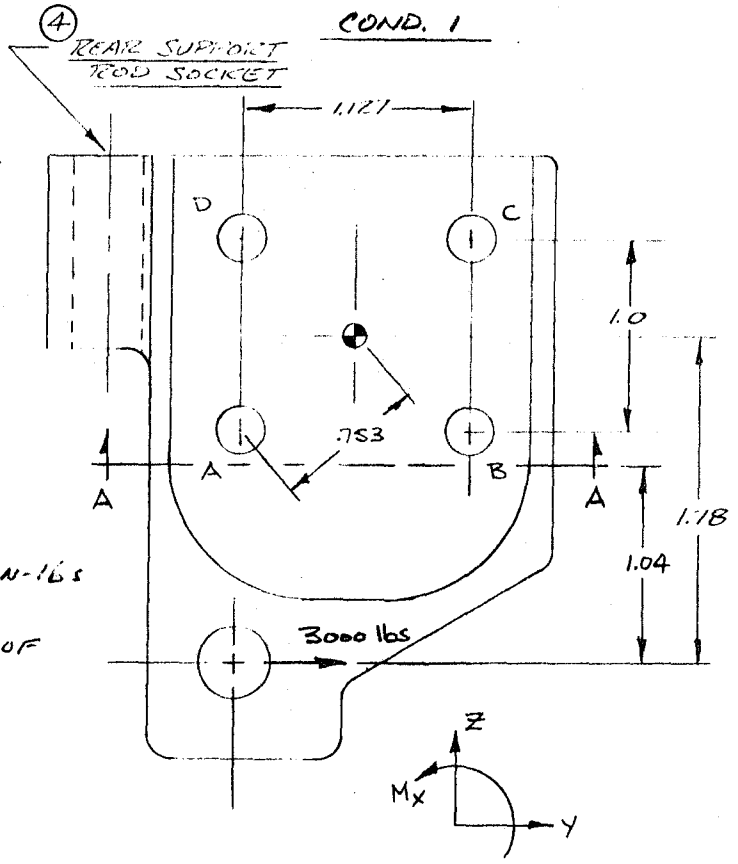
COND. 1

LOADS

ASSUMPTIONS:

(1) 1. BRACKET LOAD = 3000 lbs

2. FRICTION BETWEEN BRACKET AND ARRAY NEGLECTED




BOLT PATTERN LOAD:

$P_{BP} = B_{BKT} = 3000$ lbs

DIRECT FORCE ON BOLTS:

$F = \frac{3000}{4} = 750$ lbs

BOLT PATTERN MOMENT:

$M_{BP} = 1.78(3000) = 5350$ in-lbs

CONSTANT OF PROPORTIONALITY OF BOLT PATTERN, K:

(2) $K = \frac{5350}{4(.753)^2} = 2360$

MOMENT FORCE ON BOLT (A):

(2) $F_A = Kr_A = 2360(.753) = 1780$ lbs

TOTAL FORCE AT BOLT (A):

(3) $F_{TOT} = F + F_A = 2530$ lbs

BOLT DESIGNATION

NAS 6704 U4 BOLT — SINGLE SHEAR STRENGTH = 4650 lbs

BOLT MARGIN OF SAFETY

$M.S. = \frac{4650}{2530} - 1 = +.83$

(4) REF. SOCKET ANALYSIS - REAR TIE DOWN BRACKET, LARGE ARRAY, PAGE 61.
(3) CONSERVATIVELY ASSUME LOADS ACTING IN LINE.
(2) REF. NO. 5, PAGE 239
(1) BRACKET ASSUMED TO TAKE TOTAL $LR^3$ FORCE

FINAL ANALYSIS LRRR-300

BRACKET, INTERFACE - RIGHT REAR DWG. 2347233

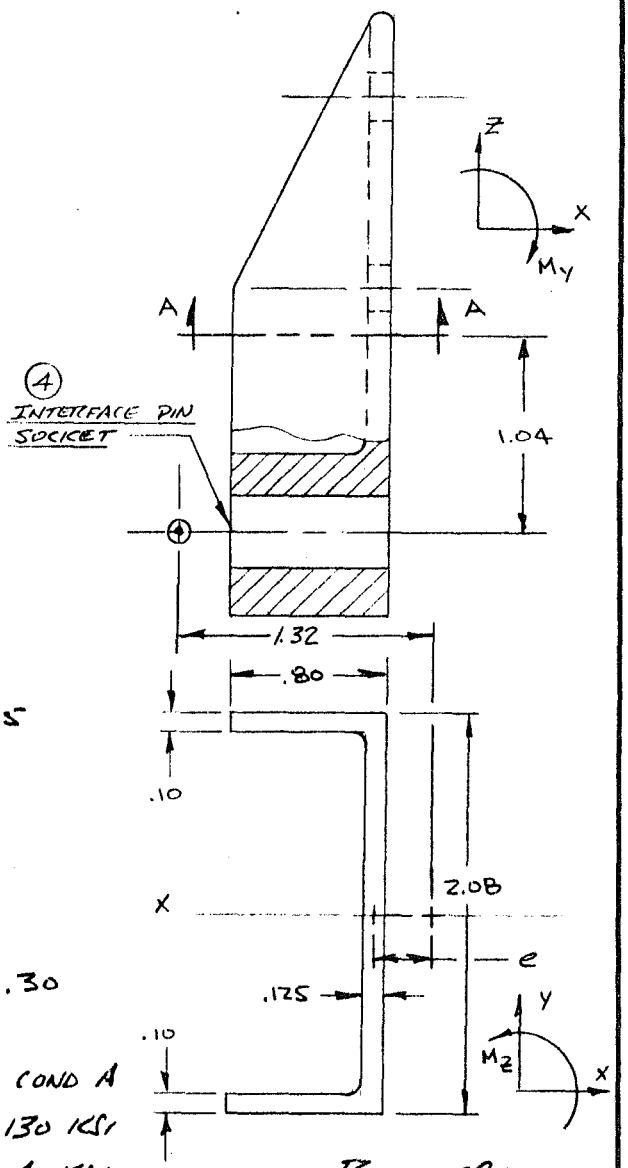
SECTION A-A COND. 1

LOADS & MOMENTS

(1) $P_{BKT} = 3000$ lbs

$M_{X_{A-A}} = 1.04\ P_{BKT} = 3120$ IN-lbs

$M_{Z_{A-A}} = 1.32\ P_{BKT} = 3960$ IN-lbs




SECTION PROPERTIES

$A = .80(2.08) - .675(1.88) = .395$

$A_{FLANGE} = .80(.10) = .08$

$I_x = \frac{.80(2.08)^3}{12} - \frac{.675(1.88)^3}{12}$

$= .226$

$I_{x/c} = .226/1.04 = .217$

$Q_x = \frac{.80(1.04)^2}{2} - \frac{.675(.94)^2}{2} = .135$

$K_x = \frac{2Q_x}{I_{x/c}} = \frac{2(.135)}{.217} = 1.24$

FLEXURAL CENTER LOCATION:

$b = .74 \quad h = 1.98 \quad t = .125$

(2) $e = \frac{b^2h^2t}{4I_x} = \frac{(.74)^2(1.98)^2(.125)}{4(.226)} = .30$

STRESSES MAT'L: TITANIUM 6AL-4V COND A

$F_{bu} = 130$ KSI

$F_b = 159$ KSI $\quad f_b = \frac{3120}{.217} = 14.4$ KSI $\quad R_b = .091$

$F_s = 80$ KSI $\quad f_s = \frac{3000}{.395} = 7.6$ KSI $\quad R_s = .045$

(3) $f_{ST} = \frac{3960}{1.98(.08)} = 25.1$ KSI $\quad R_{ST} = .314$

$U = [R_b^2 + (R_s + R_{ST})^2]^{1/2} = .42$

$M.S. = \frac{1}{U} - 1 = \underline{+1.38}$

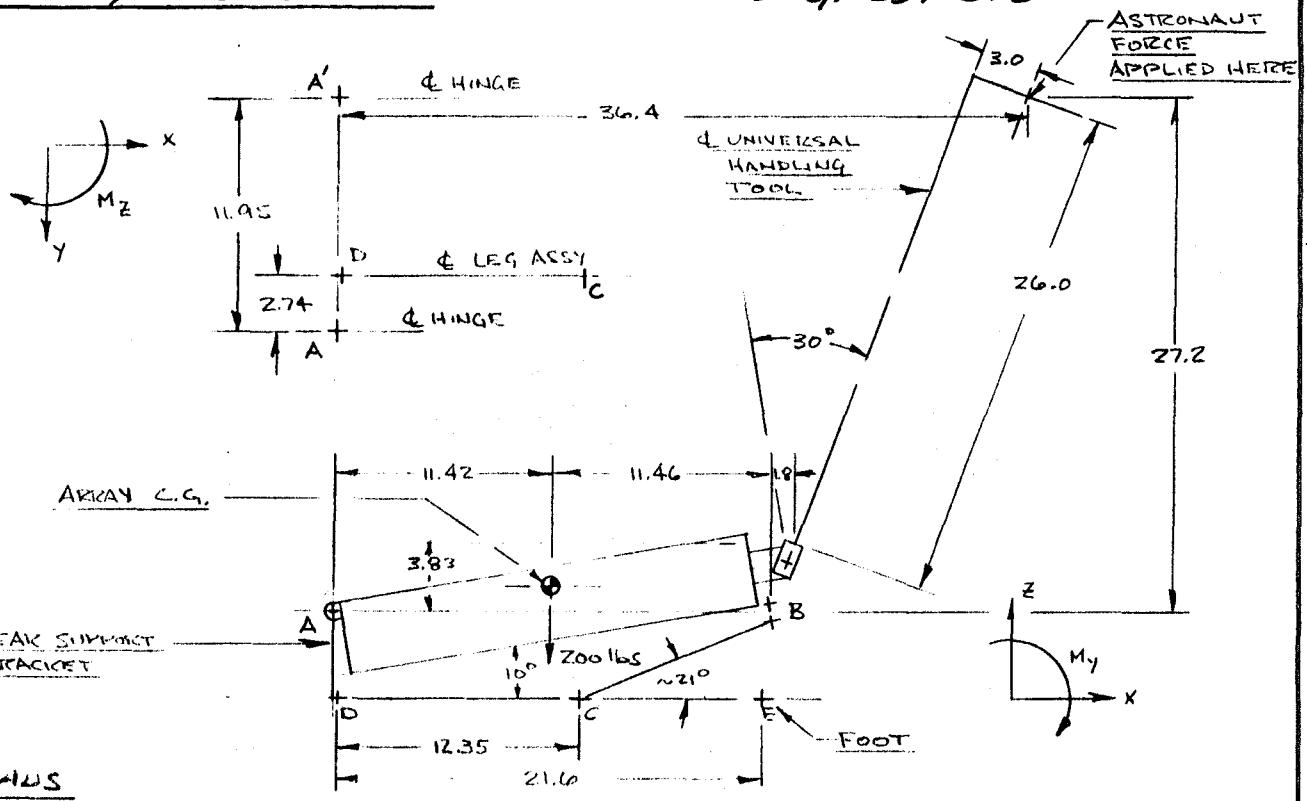
(3) TORQUE THICKEN OUT AS FLANGE SHEARS

(2) REF. NO. 4, TABLE V CASE 5

(1) REF. PAGE 19 (4) REF SOCKET ANALYSIS, PAGE 17.

FINAL ANALYSIS LRRR-300

BRACKET, REAR SUPPORT DWG. 2347348




LOADS

THE MOST CRITICAL CONDITION FOR THE REAR SUPPORT BRACKET WAS FOUND TO BE CONDITION NO. 3 WITH THE ASTRONAUT EXERTING A 45 POUND FORCE IN THE NEGATIVE Y DIRECTION. THE ARRAY IS AT A 10° ATTITUDE.

LOADS IN LEG ASSY & LUGS A & A' DUE TO A 2G ARRAY WEIGHT OF 200 POUNDS.

$$Z_B = \frac{11.42(200)}{22.88} = 100 \text{ lbs}$$

$$P_{\bar{BC}} = \frac{Z_B}{\cos 69^\circ} = \frac{100}{\cos 69^\circ} = 280 \text{ lbs}$$

$$P_{\bar{CD}} = P_{\bar{BC}} \cos 21^\circ = 280 \cos 21^\circ = 261 \text{ lbs}$$

AT A

$$X_A = \frac{9.21\, P_{\bar{CD}}}{11.95} = \frac{9.21(261)}{11.95} = 201 \text{ lbs}$$

$$Z_A = -.50\, R_{A,A'} = -50 \text{ lbs}$$

FINAL ANALYSIS LRRR-300
BRACKET, REAR SUPPORT DWG. 2347348

LOADS (CONT'D)

AT A'

$$X_{A'} = \frac{2.74\, P_{CD}}{11.95} = \frac{2.74(261)}{11.95} = 60 \text{ lbs}$$

$$Z_{A'} = -.50\, R_{AA'} = -50 \text{ lbs}$$

LOADS ON LUGS A & A' DUE TO ASTRONAUT HANDLING LOAD OF 45 POUND ULTIMATE IN THE (-Y) DIRECTION. SINCE THE ARRAY IS CONSIDERABLY STIFFER IN THE Y DIRECTION THAN THE LEG ASSY, ASSUME THE ASTRONAUT LOAD IS TRANSFERRED DIRECTLY TO THE LUGS AT A & A'.

AT A & A'

$$X_A = -X_{A'} = \frac{36.4(45)}{11.95} = 137 \text{ lbs}$$

$$Z_A = -Z_{A'} = \frac{27.2(45)}{11.95} = 103 \text{ lbs}$$

$$Y_A = Y_{A'} = -45 \text{ lbs}$$ (100-0 DISTRIBUTION DEPENDING ON LUG BEING ANALYZED)

THEN:

$$X_{A_{TOT}} = 201 + 137 = 338 \text{ lbs}$$

$$Z_{A_{TOT}} = -50 + 103 = 53 \text{ lbs}$$

$$Y_A = -45 \text{ lbs}$$ (100-0 DISTRIBUTION DEPENDING ON LUG BEING ANALYZED)

AND

$$X_{A'_{TOT}} = 60 - 137 = -77 \text{ lbs}$$

$$Z_{A'_{TOT}} = -50 - 103 = -153 \text{ lbs}$$

$$Y_{A'} = -45 \text{ lbs}$$

FINAL ANALYSIS LRRR-300
BRACKET, REAR SUPPORT DWG.- 2347348

BRACKET TWIST INVESTIGATION DURING DEPLOYMENT.

LRRR-300 DEPLOYED WITH ARRAY AT 10° ATTITUDE

LOADS (1) COND. 2

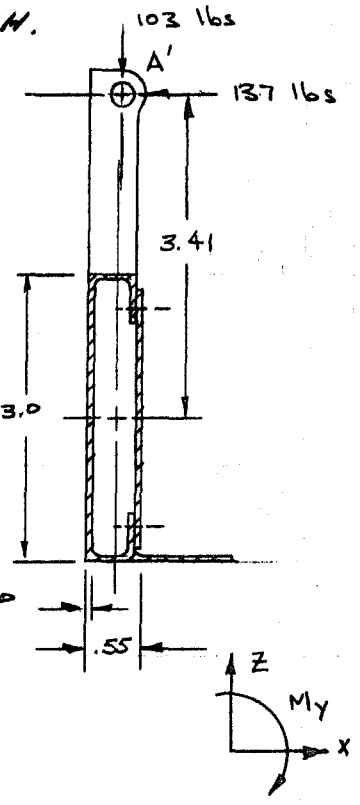
LOADS AT (A) & (A') DUE TO ASTRONAUT LOAD APPLIED IN THE (-Y) DIRECTION

$X_A = -X_{A'} = 137$ lbs

$Z_A = -Z_{A'} = 103$ lbs

$Y_A = Y_{A'}$ NEGLECT

ASSUME BRACKET IS HELD FIXED AT STIFFNER CONTAINING LUG (A) WITH STIFFNER CONTAINING LUG (A') FREE TO DEFLECT (TWIST) DUE TO THE APPLIED LOADS. CONSERVATIVELY ASSUME BRACKET SECTIONS BETWEEN STIFFNERS (A) & (A') ARE AS SHOWN IN SKETCH.




TORQUE ON SECTION:

$T = 3.41 (137) = 467$ IN-lbs

SECTION TORSIONAL CONSTANIT, K

ASSUME A BOX SECTION, WHERE:

$a = 3.0 \quad b = .55 \quad t_1 = t_2 = .05$

(2) $K = \dfrac{2tt_1(a-t)^2(b-t_1)^2}{at + bt_1 - t^2 - t_1^2}$

$= \dfrac{2(.05)^2(2.95)^2(.50)^2}{3.0(.05) + .55(.05) - 2(.05)^2} = .063$

BRACK TWIST, $\Theta$

$\Theta = \dfrac{TL}{KG} = \dfrac{467(11.95)}{.063(4\times10^6)} = .0221$ RADIAN $\simeq 1°16'$

(2) REF. No. 4, TABLE IX CASE 11.
(1) REF. PAGE 22

FINAL ANALYSIS LRRR-300

BRACKET, REAR SUPPORT DWG. 2347348

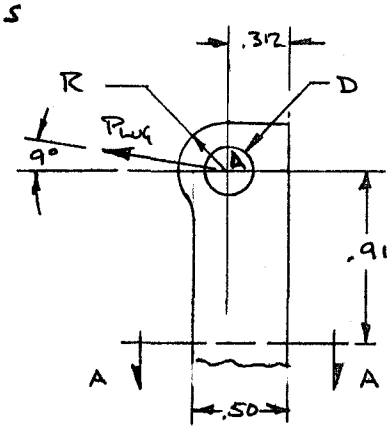
## LUG ANALYSIS - LUG A

### LUG LOADS ③

$X_A = 338$ lbs

$Z_A = 53$ lbs

RESULTANT $P_{LUG} = (X_A^2 + Z_A^2)^{1/2} = 343$ lbs




### LUG PROPERTIES ②

$D = .25$ $A_{br} = Dt = .0625$

$t = .25$ $A_t = (W-D)t = .0625$

$a = .25$ $a/D = 1.0$ $K_{br} = .83$

$W = .50$ $W/D = 2.0$ $K_t = .90$

$R = .125$ $\theta = 0°$ $C = .125$

$R/C = 1.0$ $K_1 = 1.18$ $\frac{A_{AV}}{A_{br}} = \frac{K_1 C}{2R} = \frac{1.18(.125)}{.25} = .59$ $K_{tru} = .25$

### LUG ALLOWABLES

MAT'L.: AL. ALLOY 2024-T351 $F_{tu} = 62$ KSI

$F_{tux} = 59$ KSI

ASSUME $P_{LUG}$ ACTING TRANSVERSELY

$P_{tru} = K_{tru} A_{br} F_{tux}$

$= .25(.0625)\,59000 = 920$ lbs

$$M.S. = \frac{P_{tru}}{1.15\,P_{LUG}} - 1 = \underline{1.33}$$

(1)

③ REF. PAGE 22

② REF. NO. 3, SECTION 2.30.

① FITTING FACTOR

FINAL ANALYSIS LRRR-300

BRACKET, REAR SUPPORT DWG. 2347348

LOADS

THE CONDITION IS THE SAME AS THAT ON PAGE 21 EXCEPT THE ASTRONAUT LOAD IS EXERTED IN THE (-Z) DIRECTION. (SEE SKETCH)

LOADS DUE TO ASTRONAUT FORCE:

$$Z_B = \frac{36.4(45)}{22.88} = 71.5 \text{ lbs}$$

$$P_{BC} = \frac{Z_B}{\cos 69°} = 200 \text{ lbs}$$

$$P_{CD} = P_{BC} \cos 21° = 188 \text{ lbs}$$

AT A

$$X_A = \frac{9.21\, P_{CD}}{11.95} = \frac{9.21(188)}{11.95} = 145 \text{ lbs}$$

$$Z_A = .50(Z_B - 45) = 13.6 \text{ lbs}$$

AT A'

$$X_{A'} = \frac{2.74(188)}{11.95} = 43 \text{ lbs}$$

$$Z_{A'} = .50(Z_B - 45) = 13.6 \text{ lbs}$$

TOTAL LOADS (REF. PAGES 21 & 22)

$$Z_{B_{TOT}} = Z_{B_{ARRAY}} + Z_{B_{ASTRONAUT}} = 100 + 71.5 = 171.5 \text{ lbs}$$

$$P_{BC_{TOT}} = P_{BC_{ARRAY}} + P_{BC_{ASTRONAUT}} = 280 + 200 = 480 \text{ lbs}$$

$$P_{CD_{TOT}} = P_{CD_{ARRAY}} + P_{CD_{ASTRONAUT}} = 261 + 188 = 449 \text{ lbs}$$

$$X_{A_{TOT}} = X_{A_{ARRAY}} + X_{A_{ASTRONAUT}} = 201 + 145 = 346 \text{ lbs}$$

$$Z_{A_{TOT}} = Z_{A_{ARRAY}} + Z_{A_{ASTRONAUT}} = -50 + 13.6 = -36.4 \text{ lbs}$$

$$X_{A'_{TOT}} = X_{A'_{ARRAY}} + X_{A'_{ASTRONAUT}} = 60 + 43 = 103 \text{ lbs}$$

$$Z_{A'_{TOT}} = Z_{A'_{ARRAY}} + Z_{A'_{ASTRONAUT}} = -50 + 13.6 = -36.4 \text{ lbs}$$

FINAL ANALYSIS LRRR-300

BRACKET, REAR SUPPORT DWG. 2347348

SECTION AT SUPPORT LEG SOCKET

LOADS & MOMENTS (1) COND. 3 WITH ASTRONAUT LOAD EXERTED IN (-Z) DIRECTION

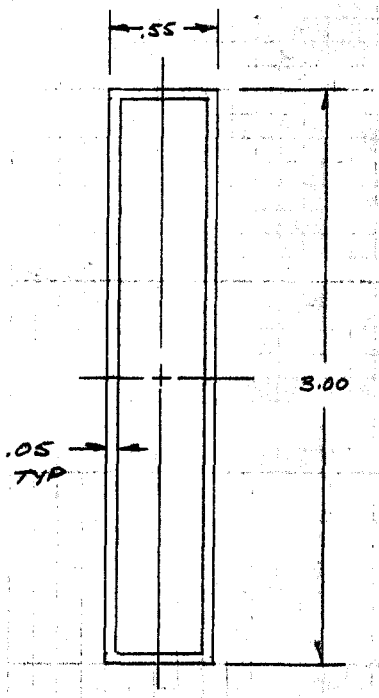
$X_A = 346$ lbs

$Z_A = -36.4$ lbs

$M_{Z_A} = -2.74 X_A = -2.74(346) = 948$ IN-lbs

$M_{Y_A}$ (TORQUE) $= 3.41 X_A = 1180$ IN-lbs

SHEAR $= (X_A^2 + Z_A^2)^{1/2} = 348$ lbs




SECTION PROPERTIES

ASSUME SECTION CONFIGURATION AS SHOWN

$A = 2(3.0).05 + 2(.45).05 = .345$

$I_Z = \frac{3.0(.55)^3}{12} - \frac{2.90(.45)^3}{12} = .0196$

$I_{Z/C} = \frac{.0196}{.275} = .0713$

$Q_Z = 3.0(.05).25 + \frac{2(.225)^2.05}{2} = .04$

$K_Z = \frac{2Q_Z}{I_{Z/C}} = \frac{2(.04)}{.0713} = 1.12$

STRESSES MAT'L: AL. ALLOY 2024-T351 $F_{tu} = 62$ KSI

$F_{bu} = 71.5$ KSI $f_b = \frac{948}{.0713} = 13.3$ KSI $R_b = .186$

$F_{su} = 37$ KSI $f_s = \frac{348}{.345} = 1.01$ KSI $R_s = .027$

(2) $f_{st} = \frac{1180}{2(.05)2.45(.50)} = 8.0$ KSI $R_{st} = .216$

$U = [R_b^2 + (R_s + R_{st})^2]^{1/2} = .253$

M.S. $= \frac{1}{U} - 1 = 2.95$

(2) REF. NO. 4, TABLE IX

(1) REF. PAGE 25

FINAL ANALYSIS LRRR-300

BRACKET, REAR SUPPORT DWG. 2347348

SECTION A-A (SEE PAGE 24)

LOADS & MOMENTS (1)

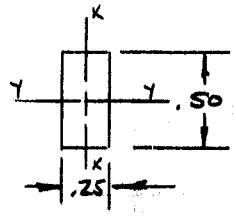
$X_A = 346$ lbs $\quad M_{X_{A-A}} = .91 Y_A = .91(45) = 41$ in-lbs

$Z_A = -36.4$ lbs $\quad M_{Z_{A-A}} = .062 Y_A = .062(45) = 2.8$ in-lbs (NEGLECT)

$Y_A = 45$ lbs $\quad M_{Y_{A-A}} = .91 X_A - .062 Z_A = .91(346) - .062(-36.4) = 317$ in-lbs

SHEAR $= (X_A^2 + Y_A^2)^{1/2} = 349$ lbs

SECTION PROPERTIES




$A = .50(.75) = .125$

$I_y = \frac{.25(.50)^3}{12} = .0026 \quad I_{y/c} = .0104 \quad K_y = 1.5$

$I_x = \frac{.50(.25)^3}{12} = .00065 \quad I_{x/c} = .0052 \quad K_x = 1.5$

STRESSES AL. ALLOY 2024-T351 $\quad F_{tu} = 62$ KSI

$F_{bu} = 90$ KSI $\quad f_{b_x} = \frac{41}{.0052} = 7.9$ KSI $\quad R_{b_x} = .088$

$f_{b_y} = \frac{317}{.0104} = 30.5$ KSI $\quad R_{b_y} = .339$

$F_{cy} = 36$ KSI $\quad f_t = \frac{36.4}{.125} = .29$ KSI $\quad R_c = .008$

$F_{su} = 37$ KSI $\quad f_s = \frac{349}{.125} = 2.79$ KSI $\quad R_s = .076$

$$U = \left\{ \left[ \left( R_{b_x}^{1.7} + R_{b_y}^{1.7} \right)^{1/1.7} + R_c \right]^2 + R_s^2 \right\}^{1/2} = .375$$

$$M.S. = \frac{1}{U} - 1 = \underline{1.67}$$

(1) REF. PAGE 25

FINAL ANALYSIS LRRR-300

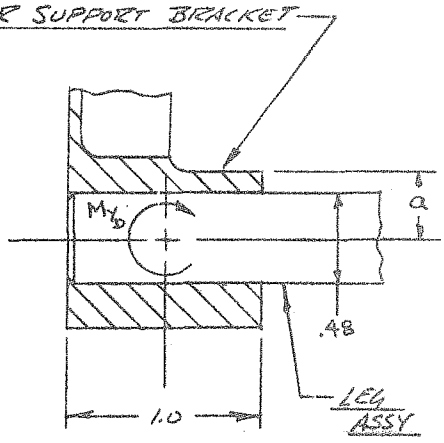
BRACKET, REAR SUPPORT DWG. 2347348

SOCKET ANALYSIS AT POINT D

SOCKET LOADS & MOMENTS

(1) $M_{y_D} = 1985$ IN-LBS

$$V_1 = \frac{M_{y_D}}{L - L_{br}} = \frac{1985}{.76} = 2610 \text{ lbs}$$




SOCKET PROPERTIES (2)

$L = 1.0$ $D = .48$ (3) $L/D = 2.08$ $L_{br}/L = .24$ $L_{br} = .24$

$a = .36$ $a/D = .75$ $C_u = .50$ (4)

ALLOWABLE SOCKET LOADS MAT'L: 2024-T351 AL. ALLOY $F_{tu} = 62$ KSI

$$V_u = C_u D L_{br} F_{tu}$$

$$= .50(.48).24(62000)$$

$$= 3570 \text{ lbs}$$

$$M.S. = \frac{V_u}{1.15 V_1} - 1 = \underline{+.19} \quad (5)$$

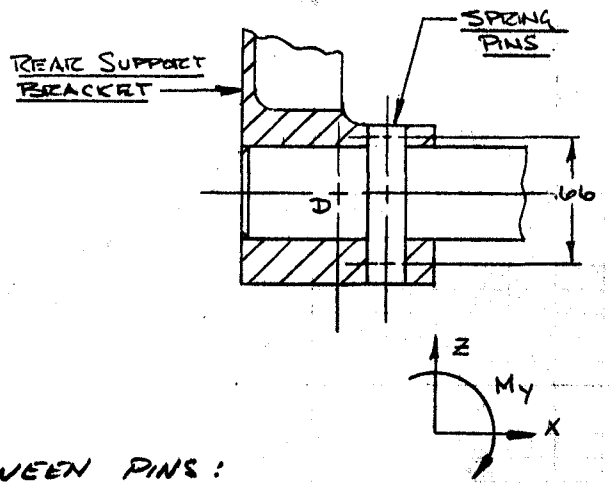
(5) FITTING FACTOR
(4) BASED ON $L/D = 1.75$
(3) SHORT SIDE OF LEG ASSUMED AS D
(2) REF. NO. 3, SECTION 2.6 - SOCKET CONSIDERED A LOOSE FIT
(1) REF. PAGE 35

FINAL ANALYSIS LRRR-300

BRACKET, REAR SUPPORT DWG. 2347348

BEARING CHECK LEG ATTACH PINS AGAINST BRACKET

LOADS & MOMENT ON BRACKET




① $X_D = -449$ lbs

① $M_{Y_D} = -1985$ IN-lbs

BEARING LOAD:

② $P_{br} = \frac{.50 M_{Y_D}}{.66} + \frac{X_D}{2}$

$= \frac{.50(1985)}{.66} + \frac{449}{2} = 1730$ lbs

ASSUME 60-40 DISTRIBUTION BETWEEN PINS:

$P_{br/PIN} = .60\, P_{br} = 1040$ lbs

BEARING PROPERTIES

PIN DIA = .188

BRACKET SOCKET WALL THICKNESS = .12

$A_{br} = Dt = .0225$

BEARING STRESSES MAT'L: 2024-T351 AL. ALLOY $F_{tu} = 62$ KSI

$F_{bry} = 71$ KSI $\quad f_{br} = \frac{1040}{.0225} = 46.2$ KSI

$M.S. = \frac{F_{bry}}{1.5 f_{br}} - 1 = \underline{+.02}$ ③

③ BEARING FACTOR

② CONSERVATIVELY ASSUME 50% OF SOCKET MOMENT TAKEN OUT IN THE PINS

① REF. PAGE 36

FINAL ANALYSIS LRRR-300

ATTACH PIN REAR SUPPORT BRACKET TO LEG ASSY

PIN LOADS

(1) $X_D = -449$ lbs

(1) $M_{Y_D} = -1985$ lbs

$$P_{PIN} = \frac{.50\, M_{Y_D}}{.66} + \frac{X_D}{2} = 1730 \text{ lbs}$$

(2)

ASSUME 60-40 DISTRIBUTION BETWEEN PINS.

$$P_{PIN} = .60\,(1730) = 1040 \text{ lbs}$$

PIN PROPERTIES

PIN DESIGNATION: NAS 561 C-6

DOUBLE SHEAR ALLOWABLE = 4400 lbs
SINGLE SHEAR " = 2200 lbs

PIN MARGIN OF SAFETY

$$M.S. = \frac{2200}{1040} - 1 = \underline{+1.11}$$

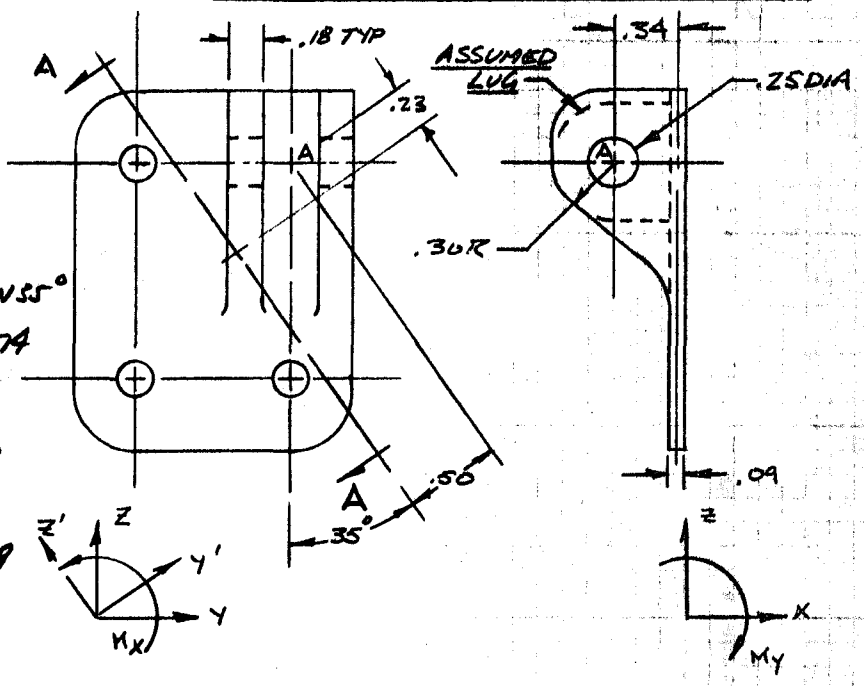
(2) CONSERVATIVELY ASSUME 50% OF SOCKET MOMENT TAKEN OUT IN THE PINS.
(1) REF. PAGE 35

FINAL ANALYSIS LRRR-300

CLEVIS, REAR PIVOT DWG. 2347343

SECTION A-A

COND 3 - ARRAY AT 10° ATTITUDE




LOADS & MOMENTS (1)

$X_A = -338$ lbs

$Y_A = 45$ lbs

$Z_A = -53$ lbs

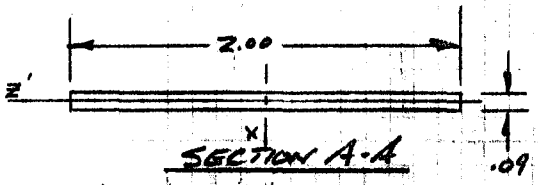
$M_{X_{A-A}} = .50 Z_A \cos 35° - .50 Y_A \sin 35°$
$= .50(-53).819 - .50(45).574$
$= 34.6$ IN-lbs

$M_{Y'_{A-A}} = .23 X_A + .34 Z_A \cos 35° - .34 Y_A \sin 35°$
$= .23(-338) + .34(-53).819 - .34(45).574$
$= 101.3$ IN-lbs

$M_{Z'_{A-A}} = -.50 X_A - .34 Y_A \cos 35° - .34 Z_A \sin 35°$
$= -.50(-338) - .34(45).819 - .34(-53).574$
$= 166.8$ IN-lbs

TENSION $= Z_A \sin 35° + Y_A \cos 35°$
$= -53\ (.574) + 45(.819) = 6.4$ lbs

SHEAR $= (Z_A \cos 35° - Y_A \sin 35°) \Rightarrow X_A$
$= [-53\ (.819) - 45(.574)] \Rightarrow 338 = 346$ lbs




SECTION A-A

SECTION PROPERTIES

$A = 2.0(.09) = .18$ $\quad a = 2.00$

$I_Y = \frac{.09(2.0)^3}{12} = .06$ $\quad I_{Y/C} = .06$ $\quad K_Y = 1.5$ $\quad b = .09$

$I_{Z'} = \frac{2.0(.09)^3}{12} = .00012$ $\quad I_{Z'/C} = .00266$ $\quad K_{Z'} = 1.5$

(2) SAND VOLUME ON SECTION, $V = \frac{b^2(3a-b)}{12} = \frac{(.09)^2[3(2.0)-.09]}{12} = .004$ IN³

(2) REF. NO. 3, SECTION 2.4

(1) REF. PAGE 22, LOADS ASSUMED IN COORDINATE SYSTEM.

FINAL ANALYSIS LRRR-300

CLEVIS, REAR PIVOT DWG. 2347343

SECTION A-A (CONT'D)

STRESSES AL. ALLOY 2024-T351 $F_{tu} = 62$ KSI

$F_b = 90.0$ KSI $f_{b_x} = \frac{34.6}{.06} = .58$ KSI $R_{b_x} = .006$

$f_{b_{z'}} = \frac{166.8}{.00266} = 62.6$ KSI $R_{b_{z'}} = .696$

$F_{tu} = 62$ KSI $f_c = \frac{6.4}{.18} = .036$ KSI $R_c = .001$

$F_{su} = 37$ KSI $f_s = \frac{346}{.18} = 1.93$ KSI $R_s = .052$

① $T_{ML} = 2VF_{su}$
$= 2(.004)37$
$= .296$ IN-K

$M_{y'_{A-A}} = .101$ IN-K $R_{ST} = .341$

$$U = \left[\left(\left[R_{b_x}^{1.7} + R_{b_{z'}}^{1.7}\right]^{\frac{1.7}{1.7}} + R_c\right)^2 + \left(R_s + R_{ST}\right)^2\right]^{1/2} = .80$$

$$M.S. = \frac{1}{U} - 1 = +.25$$

① REF. NO. 3, SECTION 2.4

FINAL ANALYSIS LRRR-300

CLEVIS, REAR PIVOT DWG. 2347343

LUG ANALYSIS COND 3 - ARRAY AT 10° ATTITUDE

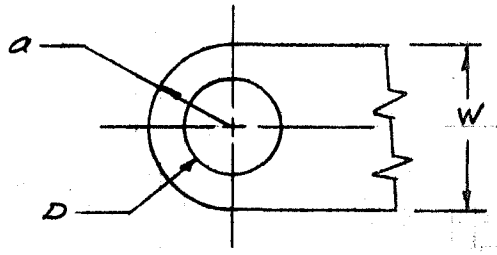
LOADS (1)

FOR LUG LOADS, ASSUME A 60-40 DISTRIBUTION

TRANSVERSE LOAD = $.60 Z_A = .60(53) = -31.8$ lbs

AXIAL LOAD = $.60 X_A = .60(-338) = -203$ lbs

LUG PROPERTIES (2)




$D = .25$ $A_{br} = Dt = .045$

$t = .18$ $A_t = (W-D)t = .063$

$a = .30$ $a/D = 1.20$ $K_{br} = .96$

$W = .60$ $W/D = 2.40$ $K_t = .94$

$R = .125$ $E = a - R = .175$ $R/E = .715$ $\theta = 0°$ $K_1 = 1.12$

$\frac{A_{av}}{A_{br}} = \frac{K_1 E}{2R} = \frac{1.12(.175)}{.25} = .785$ $K_{tru} = .50$

ALLOWABLE LUG LOADS AL. ALLOY 2024-T351 $F_{tu} = 62$ KSI

TENSION:

$P_{tu} = K_t A_t F_{tu} = .94(.063)62000 = 3670$ lbs

SHEAR-BEARING

$P_{bru} = K_{br} A_{br} F_{tu} = .96(.045)62000 = 2680$ lbs

$R_a = .076$

TRANSVERSE

$P_{tru} = K_{tru} A_{br} F_{tu} = .50(.045)62000 = 1390$ lbs

$R_{tr} = .073$

$$M.S. = \frac{1}{1.15\,(R_a^{1.6} + R_{tr}^{1.6})^{1/1.6}} - 1 = \text{AMPLE}$$

(3)

(3) FITTING FACTOR

(2) REF. NO. 3, SECTION 2.3

(1) REF PAGE 22, LOADS ASSUMED IN COORDINATE SYSTEM

FINAL ANALYSIS LRRR-300

PIVOT PIN, REAR

DWG. 2347299

PIN LOADS (1)

$X_A = -338$ lbs

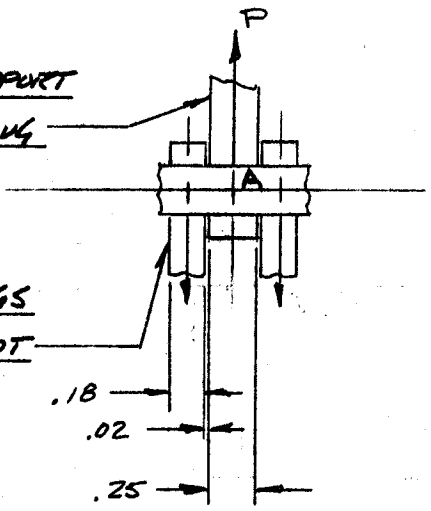
$Z_A = -53$ lbs

RESULTANT PIN LOAD:

$P_{PIN} = (X_A^2 + Z_A^2)^{1/2}$

$= 343$ lbs

B.M. $= .60\, P_{PIN}(.09 + .02 + .125) = 48.5$ in-lbs (2)




PIN PROPERTIES

OD = .25 $A = .0491$ $I = .00019$ $I/c = .00152$ $D/t = 2.0$

STRESSES MAT'L: AISI 304 STAINLESS STEEL $F_{TU} = 75$ KSI

BENDING CHECK

$F_b = 124$ KSI $f_b = \frac{48.5}{.00152} = 31.9$ KSI

$M.S. = \frac{F_b}{1.15 f_b} - 1 = \underline{2.38}$ (3)

SHEAR FACE

$F_{SU} = 40$ KSI $f_s = \frac{.60(343)}{.0491} = 4.19$ KSI

$M.S. = \frac{F_{SU}}{f_s} - 1 = \underline{\text{AMPLE}}$

(3) FITTING FACTOR
(2) ASSUME A 60-40 LOAD DISTRIBUTION
(1) REF. PAGE 22

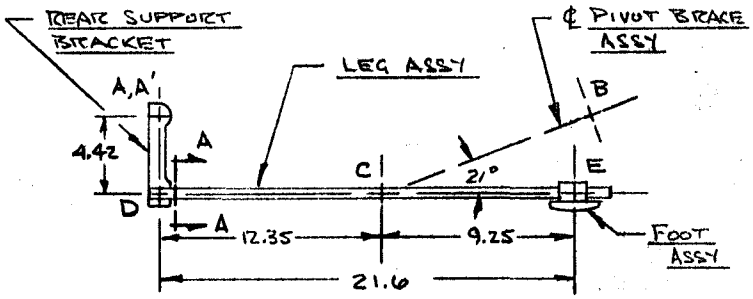
FINAL ANALYSIS LRRR-300

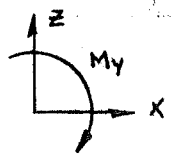
LEG ASSY

DWG. 2347342

LOADS (1)

COND 3. WITH ASTRONAUT FORCE EXERTED IN THE (-Z) DIRECTION - ARRAY AT 10° ATTITUDE




AT A,A'

$X_{A_{TOT}} + X_{A'_{TOT}} = 449$ lbs

$Z_{A_{TOT}} + Z_{A'_{TOT}} = -72.8$ lbs

AT C

$X_C = P_{CD_{TOT}} = -449$ lbs

$Z_C = -Z_{E_{TOT}} = -171.5$ lbs

AT E

$\Sigma M_{y_D} = 0 = 4.42(X_{A_{TOT}} + X_{A'_{TOT}}) - 12.35 Z_C - 21.6 Z_E$

$Z_E = \frac{4.42(449) - 12.35(-171.5)}{21.6} = 190$ lbs

AT D

$Z_D = -(Z_{A_{TOT}} + Z_{A'_{TOT}} + Z_C + Z_E)$

$= -(-72.8 - 171.5 + 190) = 54.3$ lbs

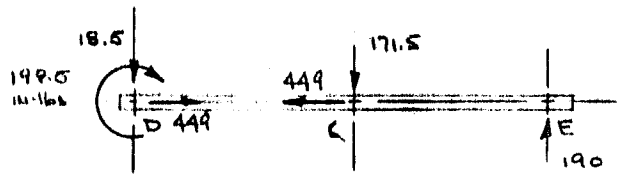
$X_D = X_{A_{TOT}} + X_{A'_{TOT}} = 449$ lbs

$M_{y_D} = 4.42(X_{A_{TOT}} + X_{A'_{TOT}}) = 1985$ in-lbs

FREE BODY DIAGRAM OF LEG ASSY

$Z_{D_{TOT}}$ ON LEG :

$Z_{D_{TOT}} = Z_{A_{TOT}} + Z_{A'_{TOT}} + Z_D = -18.5$ lbs




(1) REF. PAGE 26

FINAL ANALYSIS LRRR-300

LEG ASSY (CONT'D)

SECTION A-A (REF PAGE 35)

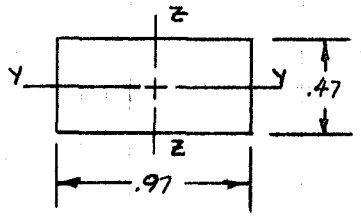
LOADS AND MOMENTS

AXIAL COMPRESSION = 449 lbs

BENDING MOMENT = 1985 IN-lbs

SHEAR = 18.5 lbs (NEGLECT)

SECTION PROPERTIES




$A = .47(.97) = .456$

$I_y = \frac{.97(.47)^3}{12} = .00839$

$I_{y/c} = .0357$ $\quad K_y = 1.5$

$I_z = \frac{.47(.97)^3}{12} = .03574$

$I_{z/c} = .0737$ $\quad K_z = 1.5$

STRESSES AL. ALLOY 2024-T351 $F_{tu} = 62$ KSI

$F_{bu} = 90$ KSI $\quad f_b = \frac{1985}{.0357} = 55.6$ KSI $\quad R_b = .619$

$F_{cy} = 36$ KSI $\quad f_c = \frac{449}{.456} = .975$ KSI $\quad R_c = .027$

$$M.S. = \frac{1}{R_b + R_c} - 1 = \underline{+.54}$$

FINAL ANALYSIS LRRR-300

DIAGONAL SUPPORT ASSY DWG. 2347345

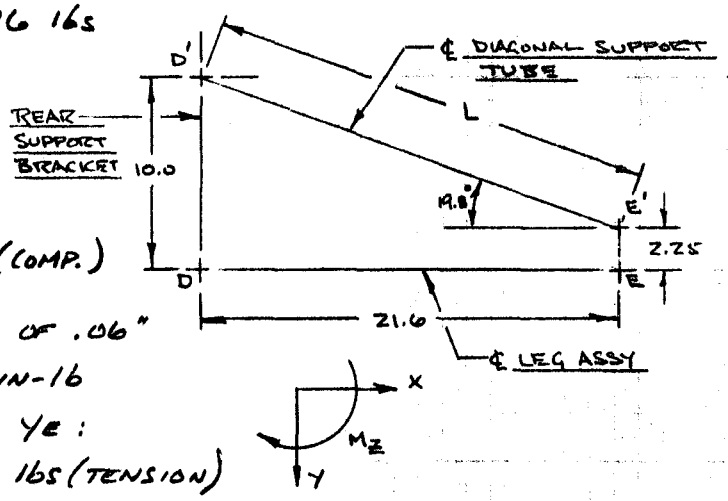
COLUMN ANALYSIS OF TUBE (P/N 2347345-1)

LOADS

COND. 3 WITH ASTRONAUT FORCE EXERTED IN THE (+Y) DIRECTION - ARRAY AT 10°

LOAD AT FOOT, $Y_E$ (SEE SKETCH PAGE 21)

$$Y_E = -\frac{36.4(45)}{21.6} = -76 \text{ lbs}$$




LOAD IN TUBE $\bar{D'E'}$ DUE TO $Y_E$:

$$P_{\bar{D'E'}} = \frac{Y_E}{\sin 19.8^\circ} = \frac{76}{.3387} = 224 \text{ lbs (COMP.)}$$

MOMENT DUE TO ECCENTRICITY OF .06"

B.M. = .06(224) = 13.4 IN-LB

LOAD IN LEG ASSY $\bar{DE}$ DUE TO $Y_E$:

$$P_{\bar{DE}} = P_{\bar{D'E'}} \cos 19.8^\circ = 211 \text{ lbs (TENSION)}$$

TUBE COLUMN PROPERTIES

OD = .50 A = .0889 $I_C$ = .0086 D/t = 7.7

ID = .37 I = .00215 t = .065 $\rho = \left(\frac{I}{A}\right)^{1/2} = .156$

(1) C = 1.0 L = L' = 22.58 $L'/\rho$ = 145

TUBE MAT'L: 6061-T6 AL. ALLOY $F_{tu}$ = 42 KSI $F_{cy}$ = 34 KSI

(2) $F_{co} = F_{cy}\left(1 + \frac{\sqrt{F_{cy}}}{1333}\right) = 34000\left[1 + \frac{(34000)^{1/2}}{2000}\right] = 37100$ PSI

(2) TRANSITIONAL $L'/\rho = 1.346\pi\left(\frac{E}{F_{co}}\right)^{1/2} = 62.2$ ∴ COLUMN IS LONG

STRESSES

(2) $F_c = \frac{\pi^2 E}{(L'/\rho)^2} = \frac{\pi^2(9.4\times10^6)}{(145)^2} = 4640$ PSI

$f_c = \frac{P_{\bar{D'E'}}}{A} = 2520$ PSI $R_c$ = .544

(3) $F_b = 1.46 F_{tu} = 61.3$ KSI $f_b = \frac{13.4}{.0086} = 1.56$ KSI $R_b$ = .026

(2) REF. NO. 6, PAGE 3.4.2.1

(1) COLUMN END FIXITY

(3) REF. NO. 3, PAGE 3.01-1

$$M.S. = \frac{1}{R_c + R_b} - 1 = \underline{+.75}$$

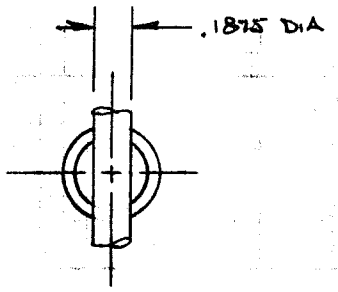
FINAL ANALYSIS LRRR-300

TUBE, DIAGONAL SUPPORT DWG. 2347345-1

BEARING CHECK - SPRING PIN AGAINST TUBE

BEARING LOAD

① $P_{D'E'} = 224$ lbs




BEARING PROPERTIES

PIN DIA = .1875
TUBE WALL = .065
$A_{br} = 2(.065).1875 = .0244$

BEARING STRESSES MAT'L -2014-T6 AL. ALLOY $F_{to} = 65$ KSI

$F_{bry} = 77$ KSI $\quad f_{br} = \frac{P_{D'E'}}{A_{br}} = \frac{224}{.0244} = 9,18$ KSI

$$M.S. = \frac{F_{bry}}{\underset{②}{1.5} f_{br}} - 1 = \underline{+4.6}$$

② BEARING FACTOR
① REF. PAGE 37

PREPARED BY JFC
CHECKED BY
REVISED BY

**ENGINEERING REPORT**
Bendix Aerospace Systems Division

DATE 12/3/70 PAGE 39
REPORT No. ATM-934
MODEL LRRZ-300

FINAL ANALYSIS LRRZ-300

BRACKET, DIAGONAL SUPPORT DWG. 2347336

BEARING CHECK - SPRING PIN AGAINST BRACKET

LOAD

BEARING LOAD = $P_{DE}$ (1) = 224 lbs

ASSUME A 60-40 LOAD DISTRIBUTION:

$P_{br}$ = .60 $P_{DE}$ = 134.5 lbs (ONE SIDE)

BEARING PROPERTIES

PIN DIA = .1875
MIN BRACKET WALL = .057
$A_{br}$ = .1875(.057) = .0107

BEARING STRESSES MAT'L: 2024-T351 AL. ALLOY $F_{tu}$ = 62 KSI

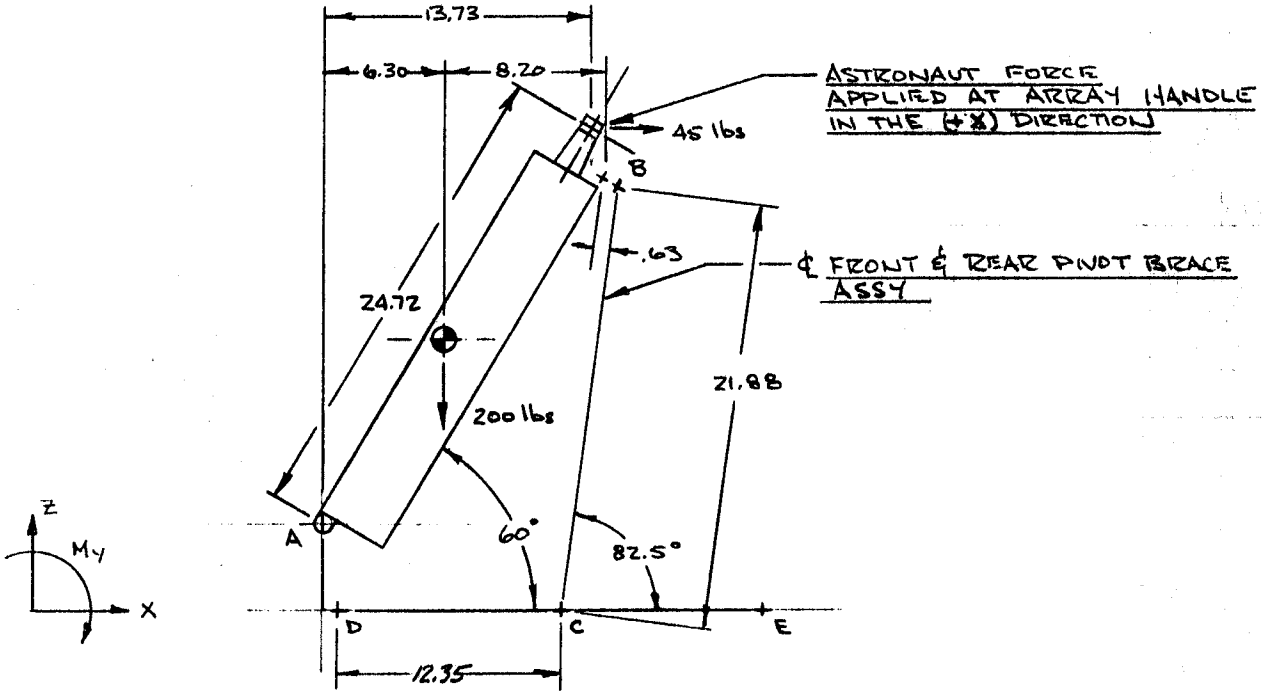
$F_{bry}$ = 63 KSI $f_{br} = \frac{134.5}{.0107} = 12.6$ KSI

$$M.S. = \frac{F_{bry}}{1.5 f_{br}\ (2)} - 1 = \underline{+2.33}$$

(2) BEARING FACTOR
(1) REF. PAGE 37

FINAL ANALYSIS LRRR-300
PIVOT BRACE, FRONT & REAR DWG'S. 2347344 & 2347347

COLUMN ANALYSIS - ARRAY AT 60° ATTITUDE




LOADS

THE MOST CRITICAL CONDITION FOR THE PIVOT BRACE ASSY AS A LONG COLUMN IS WHEN THE ARRAY IS AT A 60° ATTITUDE AND CONDITION NO. 3 WITH THE ASTRONAUT EXERTING AN ULTIMATE FORCE OF 45 POUNDS AT THE ARRAY HANDLE IN THE (+X) DIRECTION IS CONSIDERED.

COLUMN LOAD IN PIVOT BRACE ASSY (BRACE $\bar{BC}$)

$$Z_B = \frac{6.30(200) + 45(24.72\cos 30^\circ)}{14.50} = 156 \text{ lbs}$$

$$P_{\bar{BC}} = \frac{Z_B}{\sin 82.5^\circ} = \frac{156}{\sin 82.5^\circ} = 158 \text{ lbs}$$

COLUMN MOMENT = $P_{\bar{BC}}$ (OFFSET + ECCENTRICITY + SLOP)
= 158 (.63 + .06 ① + .06 ①) = 118.5 IN-lbs

① ASSUMED

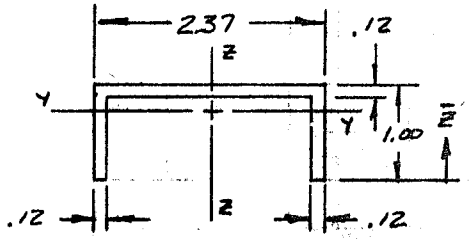
FINAL ANALYSIS LRRR-300

PIVOT BRACE, FRONT & REAR DWG's. 2347344 & 2347347

COLUMN ANALYSIS (CONT'D)

SECTION PROPERTIES

FRONT PIVOT BRACE




$A = 2(.12)1.0 + 2.12(.12) = .494$

$A_Z = .24(.50) + .254(.94) = .359 \quad \bar{Z} = .73$

$A_{NET} = .494 - 2(.192).12 = .448$

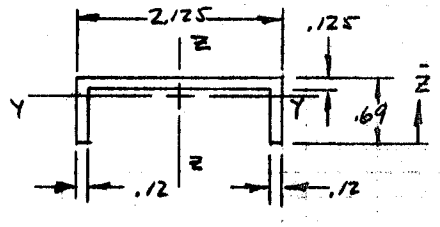
$I_Y = \frac{2(.12)(1.0)^3}{12} + \frac{2.12(.12)^3}{12} + .24(.23)^2 + .254(.21)^2 = .0439$

$I_{Y/C} = \frac{.0439}{.27} = .1626$

$Q_Y = .12(.73)^2 = .0639 \qquad K_Y = \frac{2Q_Y}{I_{Y/C}} = \frac{2(.0639)}{.1626} = .79 \text{ USE } 1.0$

$\rho_Y = \left(\frac{I_Y}{A}\right)^{1/2} = \left(\frac{.0439}{.494}\right)^{1/2} = .298$

REAR PIVOT BRACE




$A = 2(.12).69 + 1.88(.125) = .401$

$A_{NET} = .401 - 2(.192).12 = .355$

$A_Z = .166(.345) + .235(.63) = .205 \quad \bar{Z} = .51$

$I_Y = \frac{2(.12)(.69)^3}{12} + .166(.165)^2 + \frac{1.88(.125)^3}{12} + .235(.12)^2 = .01477$

$I_{Y/C} = \frac{.01477}{.18} = .0821$

$Q_Y = .166(.165) + .235(.12) = .0556 \qquad K_Y = \frac{2Q_Y}{I_{Y/C}} = \frac{2(.0556)}{.0821} = 1.35$

$\rho_Y = \left(\frac{I_Y}{A}\right)^{1/2} = \left(\frac{.01477}{.401}\right)^{1/2} = .192$

FINAL ANALYSIS LRRR-300
PIVOT BRACE, FRONT & REAR DWG'S. 2347344 & 2347347

COLUMN ANALYSIS (CONT'D)

STRESSES MAT'L AL. ALLOY 2024-T351 $F_{tu} = 62$ KSI
$F_{cy} = 36$ KSI

CONSERVATIVELY ASSUME PIVOT BRACE TO HAVE SECTION PROPERTIES OF THE REAR PIVOT BRACE FOR THE ENTIRE LENGTH OF THE COLUMN. ($L = 21.88$")

① $F_{co} = F_{cy}\left(1 + \frac{\sqrt{F_{cy}}}{1000}\right)$

$= 36000\left[1 + \frac{(36000)^{1/2}}{1000}\right] = 42800$ PSI

$L = L' = 21.88$ $\quad C = 1.0$

$L'/\rho = \frac{21.88}{.192} = 114$

① TRANSITIONAL $L'/\rho = 1.732\,\pi\left(\frac{E}{F_{co}}\right)^{1/2}$

$= 1.732\,\pi\left(\frac{10.5\times10^6}{42800}\right)^{1/2} = 85.3$ ∴ COLUMN IS LONG

ALLOWABLE COLUMN STRESS

$F_c = \frac{\pi^2 E}{(L'/\rho)^2} = \frac{\pi^2(10.5\times10^6)}{(114)^2} = 7970$ PSI

$f_c = \frac{P_{BC}}{A_{NET}} = \frac{158}{.355} = 445$ PSI

$R_c = .056$

$F_b = F_{tu} = 62$ KSI $\quad f_b = \frac{118.5}{.082} = 1445$ PSI $\quad R_b = .023$

$M.S. = \frac{1}{R_b + R_c} - 1 =$ AMPLE

① REF. No. 6, PAGE 3.4.2.1

FINAL ANALYSIS LRRR-300

PIVOT BRACE, FRONT & REAR DWG'S. 2347344 & 2347347

COLUMN ANALYSIS - ARRAY AT 10° ATTITUDE (REF. SKETCH PAGE 21)

LOADS (1) COND. 3 WITH ASTRONAUT FORCE EXERTED IN THE (-E) DIRECTION.

$Z_{B_{TOT}} = 171.5$ lbs

$P_{BC_{TOT}} = 480$ lbs

$P_{CD_{TOT}} = 449$ lbs

COLUMN MOMENT = $P_{BC_{TOT}}$ (OFFSET + ECCENTRICITY + SLOP)

$= 480(.63 + .06 + .06) = 360$ IN-lbs
(2) (3) (3)

COLUMN SECTION PROPERTIES (4)

FRONT PIVOT BRACE

$A = .494 \quad A_Z = .359 \quad \bar{z} = \frac{A_Z}{A} = .73 \quad A_{NET} = .448$

$I_y = .0439 \quad I_{y/c} = .1626$

$\rho_y = \left(\frac{I_y}{A}\right)^{1/2} = \left(\frac{.0439}{.494}\right)^{1/2} = .298$

REAR PIVOT BRACE

$A = .401 \quad A_z = .205 \quad \bar{z} = \frac{A_z}{A} = .51 \quad A_{NET} = .355$

$I_y = .01477 \quad I_{y/c} = .0821$

$\rho_y = \left(\frac{I_y}{A}\right)^{1/2} = \left(\frac{.01477}{.401}\right)^{1/2} = .192$

(4.) REF PAGE 41 FOR ANALYSIS
(3) ASSUMED
(2) REF. PAGE 40
(1) REF. PAGE 25

FINAL ANALYSIS LRRR-300
PIVOT BRACE, FRONT & REAR DWG'S. 2347344 & 2347347

COLUMN ANALYSIS (CONT'D)

STRESSES MAT'L AL. ALLOY 2024-T351 $F_{cu} = 62$ KSI, $F_{cy} = 36$ KSI

CONSERVATIVELY ASSUME PIVOT BRACE ASSY TO HAVE SECTION PROPERTIES OF THE REAR PIVOT BRACE FOR THE ENTIRE LENGTH OF THE COLUMN ($L = 11.5"$)

COLUMN YIELD STRESS

① $F_{co} = F_{cy}\left(1 + \frac{\sqrt{F_{co}}}{1000}\right)$

$= 36000\left[1 + \frac{(36000)^{1/2}}{1000}\right] = 42800$ PSI

$L = L' = 11.5"$ $\quad C = 1.0$

$L'/\rho = \frac{11.5}{.192} = 60$

① TRANSITIONAL $L'/\rho = 1.732\pi\left(\frac{E}{F_{co}}\right)^{1/2}$

$= 1.732\pi\left(\frac{10.5\times10^6}{42800}\right)^{1/2} = 85.3$ ∴ COLUMN IS SHORT

ALLOWABLE COLUMN STRESS

$F_c = F_{co}\left[1 - \frac{.385\,(L'/\rho)}{\pi\left(\frac{E}{F_{co}}\right)^{1/2}}\right]$

$= 42800\left[1 - \frac{.385(60)}{\pi\left(\frac{10.5\times10^6}{42800}\right)^{1/2}}\right] = 22.7$ KSI

$f_c = \frac{P_{EC\,TOT}}{A_{NET}} = \frac{480}{.355} = 1.35$ KSI

$R_c = .060$

$F_b = F_{cu} = 62$ KSI $\quad f_b = \frac{360}{.0821} = 4.38$ KSI

$R_b = .071$

$M.S. = \frac{1}{R_c + R_b} - 1 =$ AMPLE

① REF. NO. 6, PAGE 3.4.2.1

FINAL ANALYSIS LRRR-300

PIVOT BRACE ASSY

PIN ANALYSIS - FRONT BRACE TO REAR BRACE

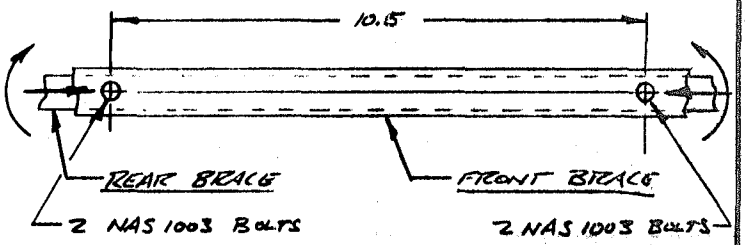
PIN LOADS

COND. 3 WITH ASTRONAUT FORCE EXERTED IN THE (-Z) DIRECTION - ARRAY AT 10° ATTITUDE

① $P_{BC_{TOT}}$ = 480 lbs

① COLUMN MOMENT = 3600 IN-lbs

ASSUME A 60-40 DISTRIBUTION BETWEEN THE TWO SETS OF PINS




LOAD PER PIN:

$$P_{PIN} = \left[(.30[480])^2 + (.30[\tfrac{360}{10.5}])^2\right]^{1/2} = 145 \text{ lbs}$$

BENDING IN PIN

$$B.M. = P_{PIN}(.06 + .01 + .06) = 145(.13) = 18.9 \text{ IN-lbs}$$

PIN PROPERTIES

PIN DIA = .1875 $A$ = .02761 $I$ = .000061 $I/c$ = .00065

STRESSES $F_{tu}$ = 140 KSI NAS 1003 BOLT

SHEAR CHECK

$F_{su}$ = 87 KSI $f_s = \frac{145}{.0276} = .53$ KSI

$$M.S. = \frac{F_{su}}{f_s} - 1 = \underline{\text{AMPLE}}$$

BENDING CHECK

$F_{bu} = F_{tu}$ = 140 KSI $f_b = \frac{18.9}{.00065} = 29.1$ KSI

$$M.S. = \frac{F_{bu}}{\text{②}\ 1.15 f_b} - 1 = \underline{+3.18}$$

② FITTING FACTOR

① REF. PAGE 25

FINAL ANALYSIS LRRR-300

PIVOT BRACE ASSY

BEARING CHECK - ATTACH PIN AGAINST BRACE

LOAD

PIN LOAD = 145 (1) lbs

BEARING PROPERTIES

PIN DIA = .1875 $t$ = .12 $A_{br} = Dt$ = .0225

STRESSES MAT'L 2024-T351 AL. ALLOY $F_{tu}$ = 62 KSI

$F_{bry}$ = 63 KSI $f_{br} = \frac{145}{.0225} = 6.45$ KSI

$$M.S. = \frac{F_{bry}}{1.5\,(2)\,f_{br}} - 1 = +6.50$$

(2) BEARING FACTOR
(1) REF. PAGE 45

FINAL ANALYSIS LRRR-300

PIVOT BRACE - REAR DWG. 2347347

LUG ANALYSIS AT BRACE SLIDE ATTACH (2)

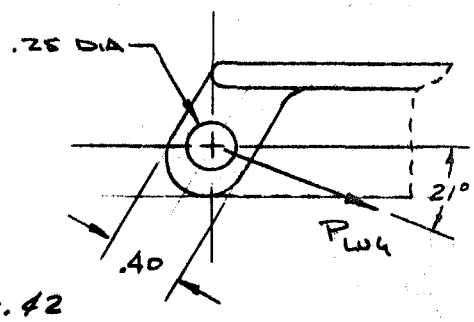
LUG LOADS

COND. 3. WITH ASTRONAUT FORCES EXERTED IN THE (-Z) DIRECTION) - ARRAY AT 10°

$P_{LUG} = P_{BC_{TOT}} = 480$ lbs (1)

ASSUME LOAD TO BE TRANSVERSE TO LUG ℄

LUG PROPERTIES (4)




$D = .25$ $A_{br} = Dt = .0625$

$a = .20$ $R = .125$ $\theta = 0°$

$w = .40$ $E = a - R = .075$

$t = .25$ $R/E = 1.67$ $K_t = 1.27$

$\frac{A_{AV}}{A_{br}} = \frac{K_t E}{2R} = \frac{1.27(.075)}{.25} = .382$ $K_{tru} = .42$

ALLOWABLE LUG LOAD MAT'L: 2024-T351 AL. ALLOY $F_{tu} = 62$ KSI

$P_{tru} = K_{tru} A_{br} F_{tu}$

$= .42(.0625)\,62000 = 1620$ lbs

$M.S. = \frac{P_{tru}}{1.15\,P_{LUG}} - 1 = \underline{+1.93}$ (3)

(4) REF. NO. 3, SECTION 2.3
(3) FITTING FACTOR
(2) REF. SKETCH ON PAGE 48
(1) CONSERVATIVE, REF PAGE 25

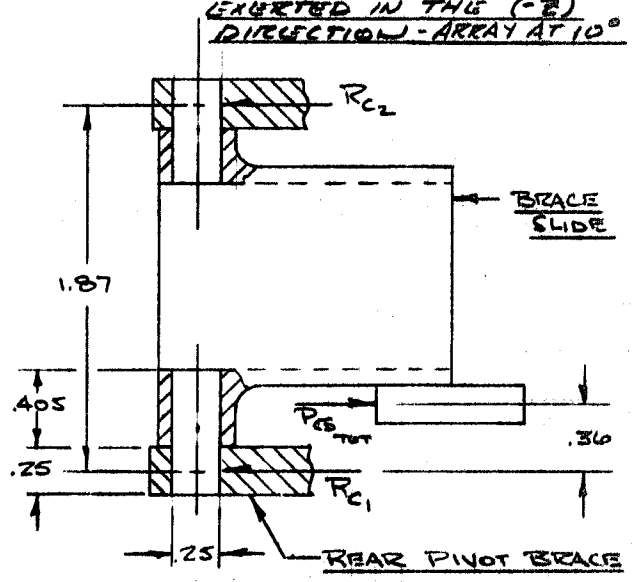
FINAL ANALYSIS LRRR-300

SLIDE, BRACE DWG. 2347341

SOCKET ANALYSIS AT PIVOT BRACE ATTACH

SOCKET LOADS (1)

COND. 3 WITH ASTRONAUT FORCE EXERTED IN THE (-Z) DIRECTION - ARRAY AT 10°




$P_{CD_{TOT}} = 449$ lbs

IN PLANE OF SLIDE:

$$R_{C_1} = \frac{1.51\, P_{CD\,TOT}}{1.87}$$

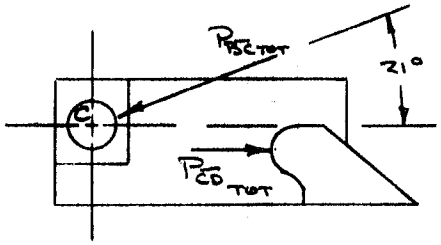
$$= \frac{1.51(449)}{1.87} = 363 \text{ lbs}$$

// TO PIVOT BRACE:

$$R_{C_{1BC}} = \frac{R_{C_1}}{\cos 21^\circ}$$

$$= \frac{363}{\cos 21^\circ} = 390 \text{ lbs}$$

SOCKET PROPERTIES (2)




$L = .385$ $\quad L/D = 1.54$

$D = .25$ $\quad L_{br}/L = .275$

$L_{br} = .106$

$a = .21$ $\quad a/D = .84$ $\quad t_1 = t_2 = .085$ $\quad d = .145$

$C_U = .77$

SOCKET LOAD

$$V_1 = \frac{R_{C_{1BC}}(d + L/2)}{L - L_{br}} + \frac{R_{C_{1BC}}}{2} = \frac{390(.338)}{.279} + 195 = 667 \text{ lbs}$$

ALLOWABLE SOCKET LOAD MAT'L AISI 304 STAINLESS STL $F_{tu} = 75$ KSI

$$V_U = C_U D L_{br} F_{tu} = .77(.25).106(75000) = 1530 \text{ lbs}$$

$$M.S. = \frac{V_U}{V_1} - 1 = \underline{+1.29}$$

(2) REF. No. 3, SECTION 2.6

(1) REF. PAGE 25

FINAL ANALYSIS LRRR-300

SLIDE, BRACE DWG. 2347341

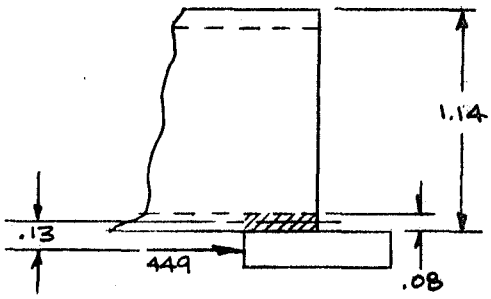
PAWL STUD TEAROUT ANALYSIS

LOADS & MOMENTS

COND. 3 WITH ASTRONAUT FORCES EXERTED IN THE (-Z) DIRECTION - ARRAY AT 10°

$P_{CD_{TOT}} = 449$ lbs (1)

B.M. = 449 (.13) = 58.3 in-lbs




ASSUMED TEAROUT SECTION (SHADED)

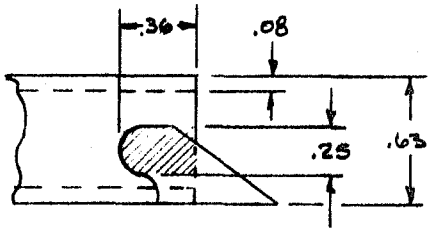
$A = 2(.36).08 + .25(.08) = .0776$

$I = \frac{2(.08)(.36)^3}{12} + .08(.25)(.18)^2$

$= .00127 \qquad I/c = \frac{.00127}{.18} = .00705$

$R = \frac{.63+1.14}{2} = .885 \qquad t = .08$

$\lambda = \frac{1.285}{(Rt)^{1/2}} = 4.83$




STRESSES MAT'L: AISI 304 STAINLESS STEEL $F_{tu} = 75$ KSI

$f_b = \frac{58.3}{.00705} = 8260$ PSI

$p = .08(8260) = 661$ lbs/in

LOCAL BENDING DUE TO $p$:

(2) $f_{bL} = \frac{5p}{2\lambda t^2} = \frac{5(661)}{2(4.83)(.08)^2} = 53.2$ KSI

TENSION DUE TO $P_{CD_{TOT}}$: $f_s = .4 f_t$ (3)

$2(.36).08(.4 f_{tL}) + .25(.08) f_{tL} = 449$

$f_{tL} = \frac{449}{.044} = 10.4$ KSI

$f_{t_{MAX}} = f_{bL} + f_{tL} = 63.6$ KSI

$M.S. = \frac{F_{tu}}{f_{t_{MAX}}} - 1 = +.18$

(3) STIFFNESS IN SHEAR & TENSION ASSUMED PROPORTIONAL TO RESPECTIVE MODULI.

(2) REF. NO. 4, TABLE XIII, CASE 8 COEFFICIENT INCREASED TO ALLOW FOR FIXED END CONDITION AT BASE OF STUD.

(1) REF. PAGE 25

FINAL ANALYSIS LRRR-300

ATTACH PIN - REAR PIVOT BRACE TO BRACE SLIDE

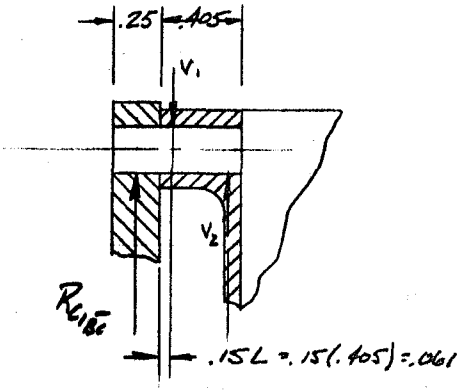
LOAD

COND 3. WITH ASTRONAUT FORCE EXERTED IN THE (-Z) DIRECTION - ARRAY AT 10°

$P_{PIN} = R_{C1_{BE}}$ ① = 390 lbs

B.M. = $R_{C1_{BE}}$ (.125 + .04 + .061)

= 390 (.226) ② = 88.1 in-lbs




PIN PROPERTIES

DIA = .25 A = .0491 I = .00019

$I/c$ = .00152 $D/t$ = 2.0

STRESSES MAT'L : AISI 303 STAINLESS STEEL $F_{tu}$ = 75 KSI

AT SHEAR FACE :

$F_{su}$ = 50 KSI $f_s = \frac{390}{.0491}$ = 7.95 KSI

$M.S. = \frac{F_{su}}{f_s} - 1 =$ +5.3

BENDING CHECK

$F_b = F_{tu}$ = 75 KSI $f_b = \frac{88.1}{.00152}$ = 58 KSI

$M.S. = \frac{F_b}{1.15 f_b}$ ③ $- 1 =$ +.12

③ FITTING FACTOR
② CLEARANCE
① REF PAGE 48

FINAL ANALYSIS LRRR-300

PAWL DWG. 2347337

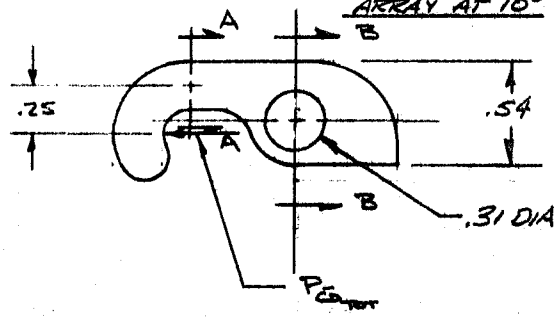
SECTION A-A CURVED BEAM ANALYSIS

COND 3. WITH ASTRONAUT FORCE EXERTED IN THE (-Z) DIRECTION ARRAY AT 10°

LOADS & MOMENTS

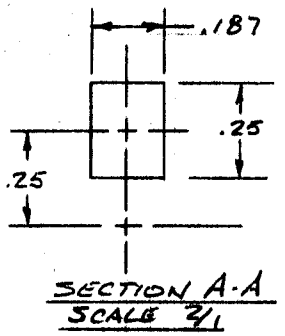
① $P_{CD_{TOT}} = 449$ lbs

$B.M._{A-A} = .25\ P_{CD_{TOT}} = 112$ IN-lbs




SECTION PROPERTIES ②

$A = .187(.25) = .0467$ $K = 1.5$




SECTION A-A
SCALE 2/1

$R = .25$
$h = .25$
$C_1 = \frac{2R}{h} = 2$
$b = .187$

ECCENTRICITY:

$$e = \frac{hC_1}{2(3C_1^2 - .8)} = \frac{.25(2)}{2[3(2)^2 - .8]} = .023$$

STRESS CONCENTRATION:

$$K_c = \frac{3C_1^2 - C_1 - .8}{3C_1(C_1 - 1)} = \frac{3(2)^2 - 2 - .8}{3(2)(2-1)} = 1.53$$

STRESSES MAT'L: 17-4 PH STAINLESS STEEL $F_{tu} = 190$ KSI

$F_b = F_{tu} = 190$ KSI $f_{MAX} = K_c \frac{6M}{bh^2} = \frac{1.53(6)112}{.187(.25)^2} = 88.1$ KSI

$R_b = .465$

$F_{tu} = 190$ KSI $f_t = \frac{449}{.0467} = 9.60$ KSI $R_t = .051$

$$M.S. = \frac{1}{R_b + R_t} - 1 = \underline{+.93}$$

② REF. No. 5, PAGE 398
① REF. PAGE 25

FINAL ANALYSIS LRRR-300

PAWL DWG. 2347337

SECTION B-B (REF SKETCH PAGE 51)

LOADS COND. 3

$P_{CP_{TOT}} = 449$

SECTION PROPERTIES

$A = .187 (.23) = .043$

STRESSES MAT'L: 17-4 PH STAINLESS STEEL $F_{tu} = 190$ KSI

$F_{tu} = 190$ KSI $\quad f_t = \frac{449}{.043} = 10.45$ KSI

$M.S. = \frac{F_{tu}}{f_t} - 1 =$ AMPLE

FINAL ANALYSIS LRRR-300

KEEPER ASSY

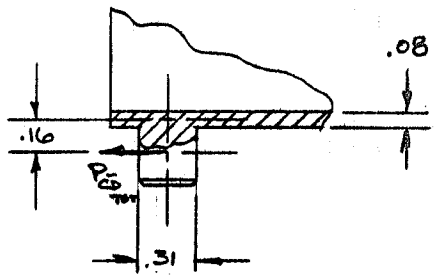
PAWL STUD TEAROUT

COND. 3 WITH ASTRONAUT FORCE EXERTED IN THE (-Z) DIRECTION - ARRAY AT 10°

(1) $P_{CD_{TOT}} = 449$ lbs

B.M. $= .16\, P_{CD} = 71.8$ in-lbs

CONSIDER PAWL STUD ACTING ON A FLAT PLATE WITH EDGES SUPPORTED AS SHOWN (2)

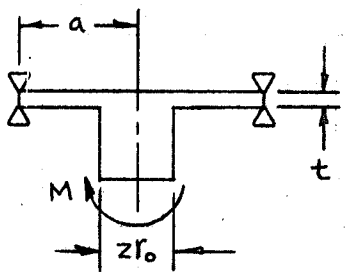



FLAT PLATE PROPERTIES

$a = \frac{.474}{2} = .237$ $\quad \nu = .30$

$r_o = .155$ $\quad t = .08$

$r_o/a = \frac{.155}{.237} = .66$ $\quad \beta = .90$ (3)




STRESSES MAT'L: AISI 304 STAINLESS STEEL $F_{tu} = 75$ KSI

$F_{tu} = 75$ KSI MAX RADIAL STRESS:

$$f_t = \frac{\beta M}{a t^2}$$

$$= \frac{.90\,(71.8)}{.237\,(.08)^2} = 42.5 \text{ KSI}$$

$$M.S. = \frac{F_{tu}}{f_t} - 1 = \underline{+.76}$$

(3) REF. NO. 4, PAGE 216
(2) REF. NO. 4, TABLE X, CASE 5
(1) REF. PAGE 25

FINAL ANALYSIS LRRR-300

KEEPER ASSY

LUG ANALYSIS

COND 3 WITH ASTRONAUT FORCE EXERTED IN THE (-Z) DIRECTION - ARRAY AT 10°

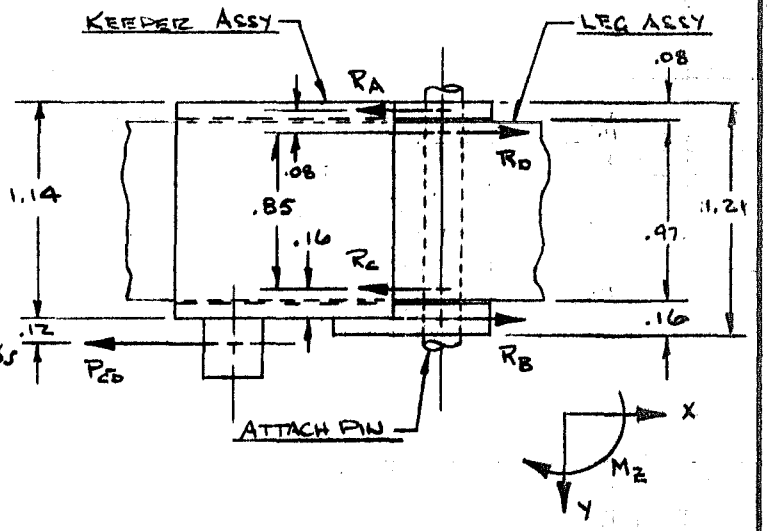
LOADS (1)

ON KEEPER ASSY

(2) $P_{CD} = -449$ lbs

$R_B = -\frac{1.21 P_{CD}}{1.09} = 499$ lbs

$R_A = -[P_{CD} + R_B] = -50$ lbs



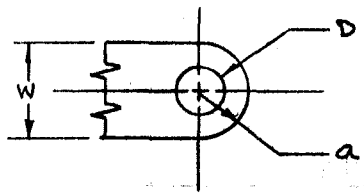

ON LEG ASSY

$R_C = \frac{.095 R_A - .996 R_B}{.863} = -598$ lbs

$R_D = -[R_A + R_B + R_C] = 149$ lbs

LUG LOAD = $R_B = 499$ lbs LUG IS AXIALLY LOADED

LUG PROPERTIES (3)




| | | | |
|---|---|---|---|
| $D = .19$ | $A_{br} = Dt = .0304$ | | |
| $t = .16$ | $A_t = (W-D)t = .0304$ | | |
| $a = .19$ | $a/D = 1.0$ | $K_{br} = .85$ | |
| $W = .38$ | $W/D = 2.0$ | $K_t = .90$ | |

LUG ALLOWABLES MAT'L : AISI 304 STAINLESS STEEL $F_{tu} = 75$ KSI

TENSION

$P_{tu} = K_t A_t F_{tu} = .90(.0304)\,75000 = 2050$ lbs

$M.S. = \frac{P_{tu}}{(4)\,1.15 P_{LUG}} - 1 = +2.57$

SHEAR BEARING

$P_{bru} = K_{br} A_{br} F_{tu} = .85(.0304)\,75000 = 1935$ lbs

$M.S. = \frac{P_{bru}}{(4)\,1.15 P_{LUG}} - 1 = +2.37$

(3) REF No. 3, SECTION 2.3
(2) REF PAGE 25
(1) FRICTION NEGLECTED
(4) FITTING FACTOR

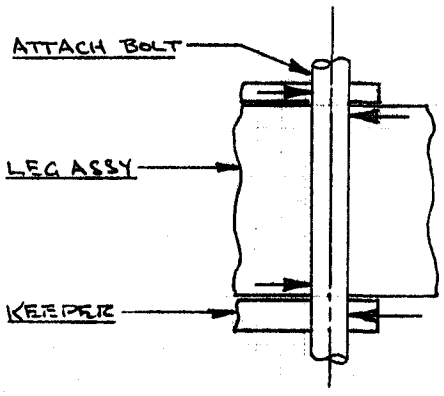
FINAL ANALYSIS LRRR-300

KEEPER ASSY

BEARING CHECK - KEEPER ATTACH BOLT AGAINST KEEPER

LOAD

$P_{BEARING} = 499$ (1) 165




BEARING PROPERTIES

BOLT DIA = .1875

LEG WALL THICKNESS, $t$ = .16

$A_{br} = Dt = .030$

BEARING STRESSES MAT'L: AISI 304 STAINLESS STEEL

$F_{bry} = 50$ KSI $\qquad f_{br} = \frac{499}{.03} = 16.6$ KSI

$$M.S. = \frac{F_{bry}}{1.5 f_{br}} - 1 = +1.01$$

(2) BEARING FACTOR

(1) REF. PAGE 54

FINAL ANALYSIS LRRR-300

BOLT, ATTACH KEEPER ASSY TO LEG ASSY

LOAD AND MOMENT (1)

$R_B$ = 499 lbs

B.M. = .16 $R_B$ = 79.8 IN-lbs

BOLT PROPERTIES

DIA = .1875

A = .02761 I = .000061 $I/c$ = .00065 D/t = 2.0

STRESSES MAT'L NAS 1003 BOLT $F_{tu}$ = 140 KSI

SHEAR FACE

$F_{su}$ = 87 KSI $f_s = \frac{499}{.02761} = 18.1$ KSI

$M.S. = \frac{F_{su}}{f_s} - 1 = +3.80$

BENDING CHECK

(3) $F_b$ = 236 KSI $f_b = \frac{79.8}{.00065} = 123$ KSI

$M.S. = \frac{F_b}{1.15 f_b} - 1 = +.67$ (2)

(3) REF. No. 3, PAGE 3.11-12
(2) FITTING FACTOR
(1) REF. PAGE 54

FINAL ANALYSIS LRRR-300

CLEVIS, FRONT BRACE DWG. 2347349

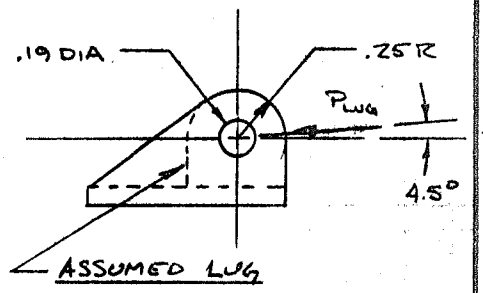
LUG ANALYSIS

CLEVIS LOAD, $P_{Bc_{TOT}}$ (1) = 480 lbs

$P_{LUG} = .60\ P_{Bc_{TOT}}$ (2) = 288 lbs

$P_{AXIAL} = P_{LUG} \sin 4.5° = 23$ lbs (5)

$P_{TRANS} = P_{LUG} \cos 4.5 \doteq 288$ lbs




LUG PROPERTIES (3)

$D = .19$ $A_{br} = Dt = .019$

$t = .10$ $A_t = (w-D)t = .031$

$a = .25$ $a/D = 1.32$ $K_{br} = 1.02$

$D = .50$ $W/D = 2.64$ $K_t = .93$

$R = .095$ $E = a - R = .155$ $R/E = .61$ $\theta = 0°$ $K_1 = 1.11$

$\frac{A_{Av}}{A_{br}} = \frac{K_1 E}{2R} = \frac{1.11(.155)}{.19} = .905$ $K_{tru} = .51$

LUG ALLOWABLES MAT'L: 2024-T351 AL. ALLOY $F_{tu} = 62$ KSI

TENSION

$$P_{tu} = K_t A_t F_{tu} = .93(.031)62000 = 1780 \text{ lbs}$$

SHEAR-BEARING

$$P_{bru} = K_{br} A_{br} F_{tu} = 1.02(.019)62000 = 1200 \text{ lbs} \quad R_a = .019$$

TRANSVERSE

$$P_{tru} = K_{tru} A_{br} F_{tu} = .51(.019)62000 = 600 \text{ lbs} \quad R_{tr} = .480$$

$$U = (R_a^{1.6} + R_{tr}^{1.6})^{1/1.6} = .482$$

$$M.S. = \frac{1}{1.15U} - 1 = +.80$$ (4)

(4) FITTING FACTOR
(3) REF. NO. 3, SECTION 2.3
(2) 60-40 LOAD DISTRIBUTION ASSUMED
(1) REF. PAGE 26
(5) TENSION CONSERVATIVELY ASSUMED

FINAL ANALYSIS LRRR-300

CLEVIS, FRONT PIVOT STRUCTURE DWG. 2347298

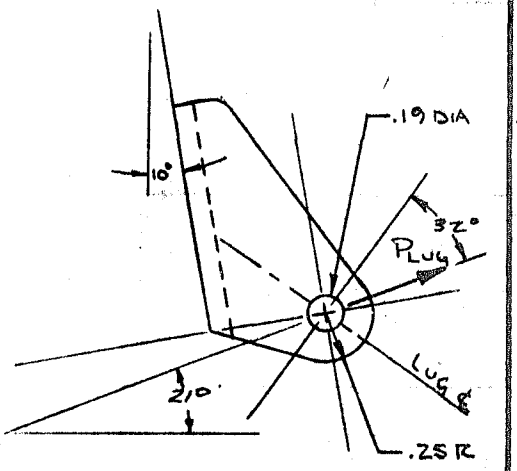
LUG ANALYSIS

CLEVIS LOAD, $P_{BC_{TOT}}$ ① = 480 lbs

$P_{LUG} = .60\ P_{BC_{TOT}}$ ② = 288 lbs

$P_{AXIAL} = P_{LUG} \sin 32° = 153$ lbs

$P_{TRANS} = P_{LUG} \cos 32° = 244$ lbs




LUG PROPERTIES ④

$D = .19$ $A_{br} = Dt = .019$

$t = .10$ $A_t = (w-D)t = .031$

$a = .25$ $a/D = 1.32$ $K_{br} = 1.02$

$W = .50$ $W/D = 2.64$ $K_t = .93$

$R = .095$ $E = a - R = .155$ $R/E = .61$ $\theta = 0°$ $K_1 = 1.11$

$$\frac{A_{AV}}{A_{br}} = \frac{K_1 E}{2R} = \frac{1.11(.155)}{.19} = .905 \qquad K_{tru} = .51$$

LUG ALLOWABLES MAT'L: 2024-T351 AL. ALLOY $F_{tu} = 62$ KSI

TENSION

$$P_{tu} = K_t A_t F_{tu} = .93(.031)\,62000 = 1780 \text{ lbs}$$

SHEAR-BEARING

$$P_{bru} = K_{br} A_{br} F_{tu} = 1.02(.019)\,62000 = 1200 \text{ lbs} \qquad R_a = .128$$

TRANSVERSE

$$P_{tru} = K_{tru} A_{br} F_{tu} = .51(.019)\,62000 = 600 \text{ lbs} \qquad R_{tu} = .407$$

$$U = \left(R_a^{1.6} + R_{tu}^{1.6}\right)^{1/1.6} = .446$$

$$M.S. = \frac{1}{1.15U} - 1 = \underline{+.95}$$ ③

④ ADD MIN. S, SECTION 2.5
⑤ FITTING FACTOR
② 60% OF LOAD DISTRIBUTION
① REF PAGE 25

FINAL ANALYSIS LRRR-300

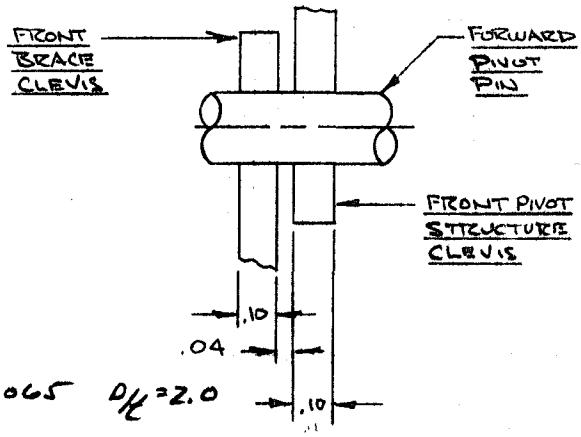
PIVOT PIN, FRONT DWG. 2347300

LOAD & MOMENT

(1) $P_{BC_{TOT}}$ = 480 lbs

(2) .60 $P_{BC_{TOT}}$ = 288 lbs

B.M. = .14 (288) = 40.3 in-lb (2)




PIN PROPERTIES

PIN DIA = .1875

A = .02761 I = .000061 $I/c$ = .00065 $D/t$ = 2.0

STRESSES MAT'L AISI 304 STAINLESS STEEL $F_{tu}$ = 75 KSI

SHEAR CHECK

$F_{su}$ = 40 KSI $f_s = \frac{288}{.02761} = 10.45$ KSI

$M.S. = \frac{F_s}{f_s} - 1 = \underline{+2.83}$

BENDING CHECK

$F_b$ = 124 KSI $f_b = \frac{40.3}{.00065} = 62.0$ KSI

$M.S. = \frac{F_b}{1.15 f_b} - 1 = \underline{+.74}$ (3)

(3) FITTING FACTOR

(2) ASSUME CLEVIS SHIFTED TO ONE SIDE & 60% OF $P_{BC_{TOT}}$ LOAD ON MOST SEPARATED SET OF LUGS.

(1) REF PAGE 25

FINAL ANALYSIS LRRR-300

BRACKET, REAR TIE-DOWN – LARGE ARRAY DWG. 2347236

LUG ANALYSIS COND. 1

ASSUMPTIONS:

1. SMALL ARRAY WEIGHT ≈ 30 lbs
2. BRACKET SEES NO LOAD IN THE X-DIRECTION
3. EQUAL LOAD DISTRIBUTION ON THE TIE DOWN BRACKETS AND HINGES (Y & Z-DIRECTIONS).

LUG LOADS

SMALL ARRAY FORCE AT 30 G'S

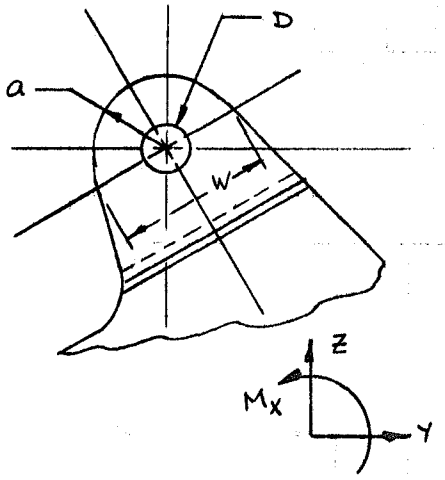
$P = 30(30) = 900$ lbs

BRACKET LOAD $= .25(900) = 225$ lbs

$P_{AXIAL} = P_{TRANSVERSE} = P_{BRACKET} = 225$ lbs

60-40 DISTRIBUTION BETWEEN LUGS:

(1) $P_{a/LUG} = (1) P_{tr/LUG} = .60(225) = 135$ lbs




LUG PROPERTIES (2)

| | | | |
|---|---|---|---|
| $D = .25$ | $A_{br} = Dt = .01$ | | |
| $t = .04$ (4) | $A_t = (W-D)t = .02$ | | |
| $a = .38$ | $a/D = 1.52$ | $K_{br} = 1.08$ | |
| $W = .76$ | $W/D = 3.04$ | $K_t = .92$ | |
| $R = .125$ | $E = a - R = .255$ | $\Theta = 0°$ | |
| $R/E = .50$ | $K_1 = 1.095$ | $\frac{A_{AV}}{A_{br}} = \frac{K_1 E}{2R} = 1.095$ | $K_{tru} = .52$ |

LUG ALLOWABLES MAT'L: 2024-T351 AL. ALLOY $F_{tu} = 62$ KSI

TENSION

$P_{tu} = K_t A_t F_{tu} = .92(.02)\,62000 = 1140$ lbs

SHEAR-BEARING

$P_{bru} = K_{br} A_{br} F_{tu} = 1.08(.01)\,62000 = 670$ lbs

$M.S. = \frac{P_{bru}}{(3)\,1.15\,P_a} - 1 = \underline{+3.31}$

TRANSVERSE

$P_{tru} = K_{tru} A_{br} F_{tu} = .52(.01)\,62000 = 322$ lbs

$M.S. = \frac{P_{tru}}{(3)\,1.5\,P_{tr}} - 1 = \underline{+1.07}$

(3) FITTING FACTOR
(2) REF. NO. 3, SECTION 2.3
(1) ACTING SEPARATELY
(4) THIS THICKNESS ASSUMED FOR TOTAL T OF LUG

FINAL ANALYSIS LRRR-300

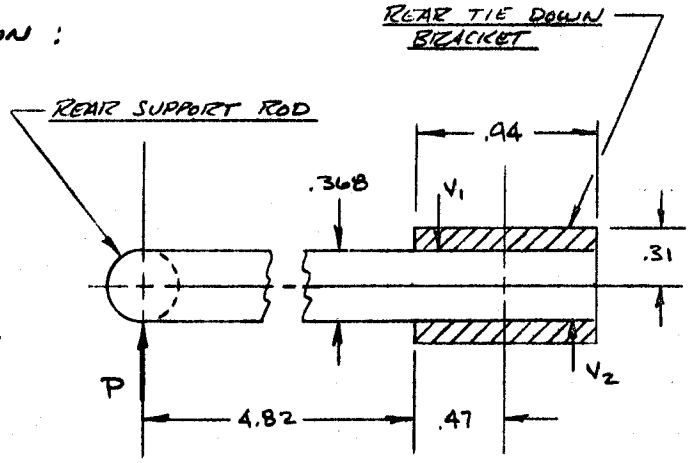
BRACKET, REAR TIE-DOWN - LARGE ARRAY DWG. 2347236

SOCKET ANALYSIS (1)

FOR ASSUMPTIONS, REF PAGE 88

REAR SUPPORT ROD REACTION:

$P_{R.S.R} = 51.4$ lbs




SOCKET LOAD

$$V_1 = \frac{P(d + L_2)}{L - L_{br}} + \frac{P}{2}$$

$$= \frac{51.4\,(5.29)}{.69} + \frac{51.4}{2}$$

$$= 419 \text{ lbs}$$

SOCKET PROPERTIES

$D = .368$ $\quad L/D = 2.55$

$L = .94$ $\quad L_{br}/L = .24$ $\quad L_{br} = .226$

$t = t_1 = .126$

$a = .31$ $\quad a/D = .84$ $\quad C_u = .67$ (2)

SOCKET ALLOWABLES MAT'L: 2024-T351 AL. ALLOY $F_{tu} = 62$ KSI

$$V_u = C_u D L_{br} F_{tu}$$

$$= .67(.368).226(62000)$$

$$= 3460 \text{ lbs}$$

$$M.S. = \frac{V_u}{1.15\,V_1} - 1 = +6.19$$ (3)

(3) FITTING FACTOR

(2) BASED ON $L/D = 1.75$

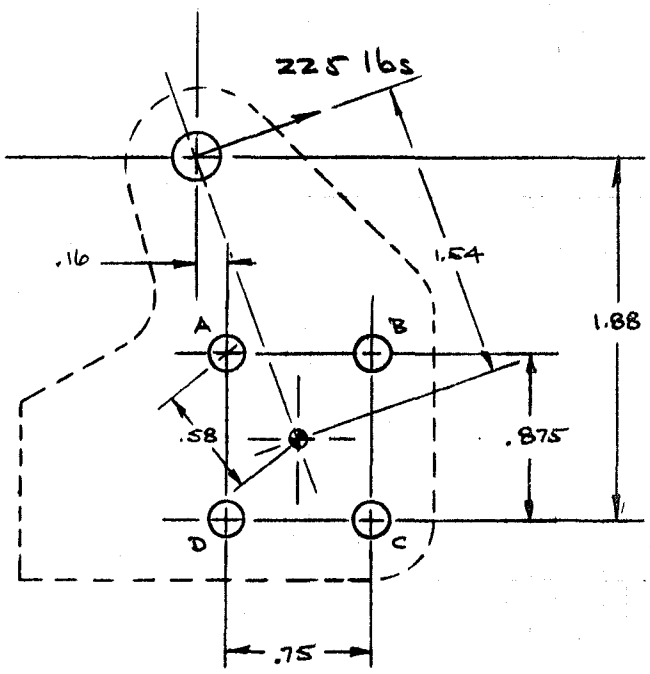
(1) REF. NO. 3, SECTION 2.60

FINAL ANALYSIS LRRR-300

BOLT PATTERN - REAR TIE DOWN BRACKET TO LARGE ARRAY ANALYSIS

LOADS

COND. 1




(1) $P_{BRACKET\ LUG} = 225$ lbs

DIRECT FORCE ON BOLTS:

$$F = \frac{225}{4} = 56.3 \text{ lbs}$$

CONSTANT OF PROPORTIONALITY OF BOLT PATTERN, K:

(2) $$K = \frac{1.54(225)}{4(.58)^2} = 257$$

MOMENT FORCE ON BOLTS:

(2) $F_M = Kr = 257(.58)$
$= 149$ lbs

MAXIMUM FORCE AT BOLT (A)

(3) $F_{BOLT} = F + F_M = 205.3$ lbs

BOLT DESIGNATION

AN 3 CRES BOLT

ULT. TENSILE STRENGTH = 2210 lbs
YLD. TENSILE STRENGTH = 1690 lbs
SINGLE SHEAR STRENGTH = 2125 lbs

BOLT MARGIN OF SAFETY

$$M.S. = \frac{2125}{205.3} - 1 = +9.35$$

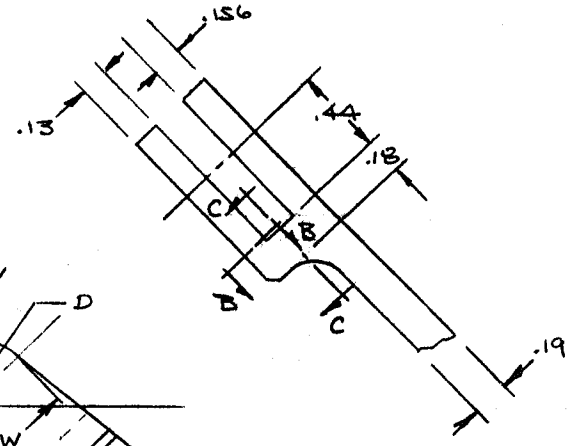
(3) CONSERVATIVELY ASSUME LOADS ACTING IN LINE.
(2) REF. NO. 5, PAGE 239
(1) REF. PAGE 60

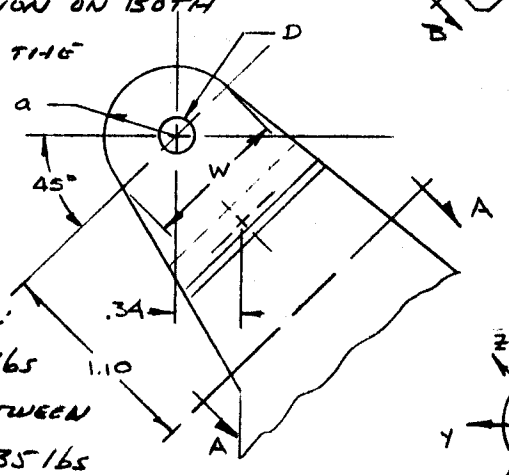
FINAL ANALYSIS LRRR-300
BRACKET, HANDLE R.H. DWG. 2347241

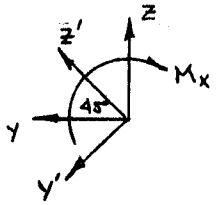
LUG ANALYSIS - TIE DOWN LUG COND. 1

ASSUMPTIONS:

1. SMALL ARRAY WEIGHT ≈ 30 lbs
2. EQUAL LOAD DISTRIBUTION ON HANDLE BRACKETS' HINGES IN THE X- DIRECTION
3. EQUAL LOAD DISTRIBUTION ON BOTH BRACKETS & HINGES IN THE Y & Z DIRECTIONS.




LUG LOADS

SMALL ARRAY FORCE:
$P = 30(30) = 900$ lbs
TOTAL BRACKET LUG LOAD:
$P_{BKT} = .25(900) = 225$ lbs
60 - 40 DISTRIBUTION BETWEEN LUGS: (1) $P_{q/Lug}$ (1) $P_{tu/Lug} = 135$ lbs

LUG PROPERTIES (2)

$D = .19$ $A_{br} = Dt = .0228$
$t = .12$ $A_t = (W-D)t = .0684$
$a = .38$ $a/D = 2.0$ $K_{br} = 1.14$
$W = .76$ $W/D = 4.0$ $K_t = .29$

$R = .095$ $E = a - R = .285$ $\theta = 0°$
$R/E = .33$ $K_1 = 1.06$
$\frac{A_{AV}}{A_{br}} = \frac{K_1 E}{2R} = 1.59$ $K_{tru} = .34$

LUG ALLOWABLES MAT'L: 6061-T651 AL. ALLOY $F_{tu} = 42$ KSI

TENSION

$P_{tu} = K_t A_t F_{tu} = .29(.0684)/42000 = 835$ lbs

$M.S. = \frac{P_{tu}}{1.15 P_q (3)} - 1 = \underline{+4.37}$

SHEAR BEARING

$P_{bru} = K_{br} A_{br} F_{tu} = 1.14(.0228)\ 42000 = 1092$ lbs

TRANSVERSE

$P_{tru} = K_{tru} A_{br} F_{tu} = .34(.0228)\ 42000 = 325$ lbs

$M.S. = \frac{P_{tru}}{1.15 P_{tr} (3)} - 1 = \underline{+1.09}$

(3) FITTING FACTOR
(2) REF. NO. 3, SECTION 2.30
(1) ACTING SEPARATELY

FINAL ANALYSIS LRRR -300

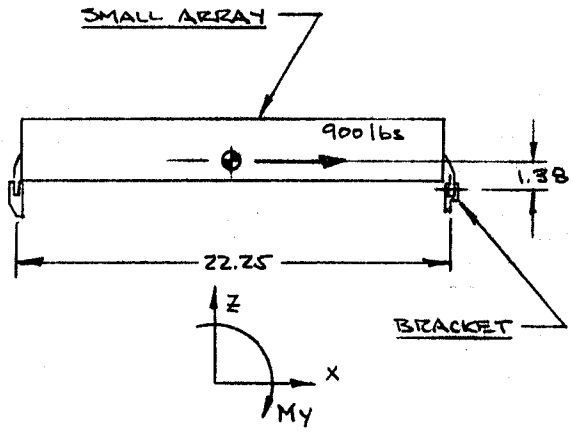
BRACKET, HANDLE R.H. DWG. 2347241

SECTION A-A

① LOADS AND MOMENTS COND. 1

$P_{X_{BKT}} = \frac{900}{3} = 300$ lbs

$P_{Z_{BKT}} = \frac{900(1.38)}{22.25} = 56$ lbs



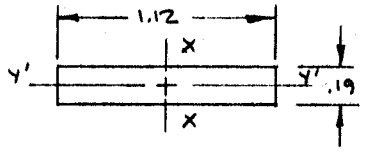

SECTION LOADS & MOMENTS

$SHEAR = \left[P_{X_{BKT}}^2 + (P_{Z_{BKT}} \sin 45°)^2\right]^{1/2}$
$= 303$ lbs

$COMP. = P_{Z_{BKT}} \cos 45° = 39.6$ lbs

$M_{y'_{A-A}} = 1.10\, P_{X_{BKT}} = 330$ IN-lbs

$M_{X_{A-A}} = 1.10\,(P_{Z_{BKT}} \sin 45°) = 43.5$ IN-lbs




SECTION PROPERTIES

$A = 1.12(.19) = .213$

$I_X = \frac{.19(1.12)^3}{12} = .0222$ $\quad I_{X/C} = .0396$ $\quad K_X = 1.5$

$I_{Y'} = \frac{1.12(.19)^3}{12} = .00063$ $\quad I_{Y'/C} = .0066$ $\quad K_{Y'} = 1.5$

STRESSES MAT'L: 6061-T651 AL. ALLOY $F_{tu} = 42$ KSI

② $F_{b_{y'}} = 1.45 F_{tu} = 61$ KSI $\quad f_{b_{y'}} = \frac{330}{.0066} = 50$ KSI $\quad R_{b_{y'}} = .820$

$F_{bx} = 61$ KSI $\quad f_{bx} = \frac{43.5}{.0396} = 1.10$ KSI $\quad R_{b_x} = .018$

$F_{cy} = 35$ KSI $\quad f_c = \frac{39.6}{.213} = .186$ KSI $\quad R_c = .005$

$F_{su} = 27$ KSI $\quad f_s = \frac{303}{.213} = 1.42$ KSI $\quad R_s = .053$

$U = \left[(R_{b_{y'}} + R_{b_x} + R_c)^2 + R_s^2\right]^{1/2} = .845$

$M.S. = \frac{1}{U} - 1 = +.18$

② REF. No. 3, PAGE 3.01-3
① REF. PAGE 63

FINAL ANALYSIS LRRR-300

BRACKET, HANDLE R.H. DWG. 2347241

SECTION B-B

(1) LOADS AND MOMENTS COND. 1

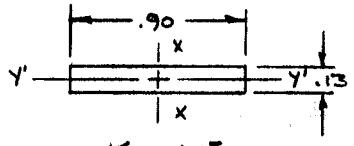
$$\text{SHEAR} = \left[P_{X_{BKT}}^2 + (.60\,P_{Z_{BKT}} \sin 45^\circ)^2\right]^{1/2} = 301 \text{ lbs}$$

$$\text{COMP.} = .60\,P_{Z_{BKT}} \cos 45^\circ = 24 \text{ lbs}$$

$$M_{y'_{B\text{-}B}} = .44\,P_{X_{BKT}} = 134 \text{ in-lbs}$$

$$M_{X_{A\text{-}A}} = .44\,(.60\,P_{Z_{BKT}} \sin 45^\circ) = 10.6 \text{ in-lbs}$$

SECTION PROPERTIES




$A = .13(.90) = .117$

$I_X = \frac{.13(.90)^3}{12} = .0079$ $\quad I_{x/c} = .0175$ $\quad K_x = 1.5$

$I_{Y'} = \frac{.90(.13)^3}{12} = .00016$ $\quad I_{y'/c} = .00246$ $\quad K_{y'} = 1.5$

STRESSES MAT'L: 6061-T651 AL. ALLOY $F_{tu} = 42$ KSI

$F_{by'} = 61$ KSI $\quad f_{by'} = \frac{134}{.00246} = 54.5$ KSI $\quad R_{b_{y'}} = .892$

$F_{bx} = 61$ KSI $\quad f_{bx} = \frac{10.6}{.0175} = .902$ KSI $\quad R_{b_x} = .015$

$F_{cy} = 35$ KSI $\quad f_c = \frac{24}{.117} = .205$ KSI $\quad R_c = .006$

$F_{su} = 27$ KSI $\quad f_s = \frac{301}{.117} = 2.81$ KSI $\quad R_s = .104$

$$U = \left[(R_{b_{y'}} + R_{b_x} + R_c)^2 + R_s^2\right]^{1/2} = .92$$

$$M.S. = \frac{1}{U} - 1 = \underline{+.08}$$

(1) REF. PAGE 64

FINAL ANALYSIS LRRR-300

BRACKET, HANDLE R.H. DWG. 2347241

SECTION C-C

(1) LOADS AND MOMENTS

SHEAR = $.60\, P_{Z_{BKT}}$ = 33.6 lbs

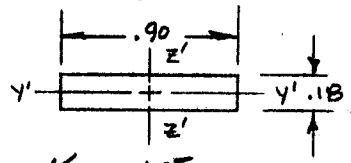
TENSION = $P_{X_{BKT}}$ = 300 lbs

$M_{X_{C\text{-}C}} = .53(.60\, P_{Z_{BKT}} \sin 45°)$ = 12.6 in-lbs

$M_{y'_{C\text{-}C}} = .53\, P_{X_{BKT}} + .16(.60 P_{Z_{BKT}} \cos 45°)$ = 163 in-lbs

$M_{z'_{C\text{-}C}} = .16(.60 P_{Z_{BKT}} \sin 45°)$ = 4.0 in-lbs (NEGLECT)

SECTION PROPERTIES




$A = .18(.90) = .162$

$I_{y'} = \frac{.90(.18)^3}{12} = .00043$ $\quad I_{y'/c} = .0048$ $\quad K_{y'} = 1.5$

(2) CALCULATED SAND VOLUME:

$$Vol = \frac{b^2(3a-b)}{12} = \frac{(.18)^2[3(.90)-.18]}{12} = .0068\ in^3$$

STRESSES MAT'L: 6061-T651 AL. ALLOY $F_{tu}$ = 42 KSI

| | | |
|---|---|---|
| $F_{by'}$ = 61 KSI | $f_{by'} = \frac{163}{.0048}$ = 34 KSI | $R_{by'}$ = .557 |
| $F_{tu}$ = 42 KSI | $f_t = \frac{300}{.162}$ = 1.85 KSI | $R_t$ = .044 |
| $F_{su}$ = 27 KSI | $f_s = \frac{33.6}{.162}$ = .208 KSI | $R_s$ = .008 |

(2) $T_{ALL} = 2V F_{su}$

$= 2(.0068)\, 27000$ = 367 in-lbs $\quad M_{X_{C\text{-}C}}$ = 12.6 in-lbs $\quad R_{ST}$ = .034

$$U = \left[(R_{by'} + R_t)^2 + (R_s + R_{ST})^2\right]^{1/2} = .602$$

$$M.S. = \frac{1}{U} - 1 = \underline{+.66}$$

(2) REF NO. 3, PAGE 2.40-1

(1) REF PAGE 64

FINAL ANALYSIS LRRR-300

BRACKET, HANDLE R.H. DWG. 2347241

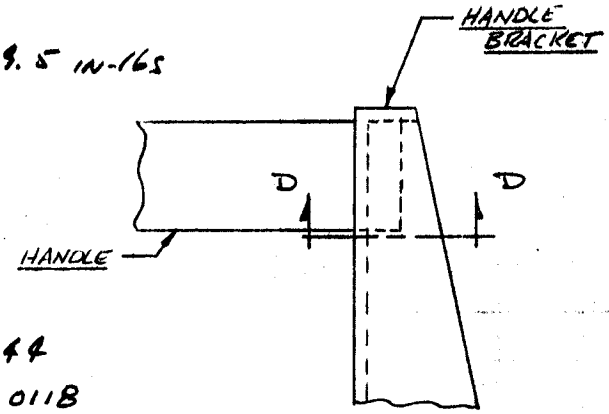
SECTION D-D

① LOADS AND MOMENTS COND. 3

$W = 2(100) = 200$ lbs

② $M_{Z_{D-D}} = \frac{Wl}{8} = \frac{200(6.38)}{8} = 159.5$ IN-lbs

TENSION $= \frac{W}{2} = 100$ lbs




SECTION PROPERTIES

$A = 2(.43).06 + 2(.19).06 = .0744$

$A_y = .0516(.215) + .0228(.03) = .0118$

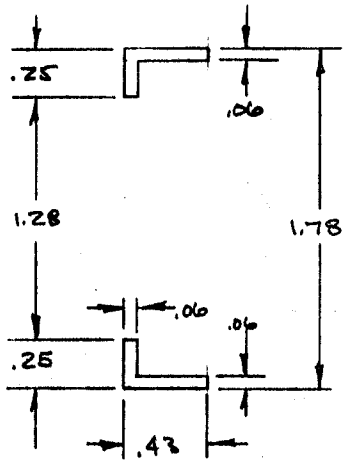
$\bar{y} = \frac{\Sigma A_y}{A} = .16$

$I_Z = 2\left[\frac{.06(.43)^3}{12} + .0516(.055)^2 + \frac{.19(.06)^3}{12} + .0228(.13)^2\right] = .00187$

$I_{Z/C} = \frac{.00187}{.16} = .0117$

$Q_Z = \frac{.12(.27)^2}{2} = .0044$

$K_Z = \frac{2Q_Z}{I_{Z/C}} = \frac{2(.0044)}{.0117} = .75$ USE 1.0




STRESSES MAT'L: 6061-T651 AL. ALLOY

$f_b = \frac{159.5}{.0117} = 13620$ PSI

$f_t = \frac{100}{.0744} = 1350$ PSI

$M.S. = \frac{F_{ty}}{f_b + f_t} - 1 = \frac{③\ 17000}{14970} - 1 = +.13$

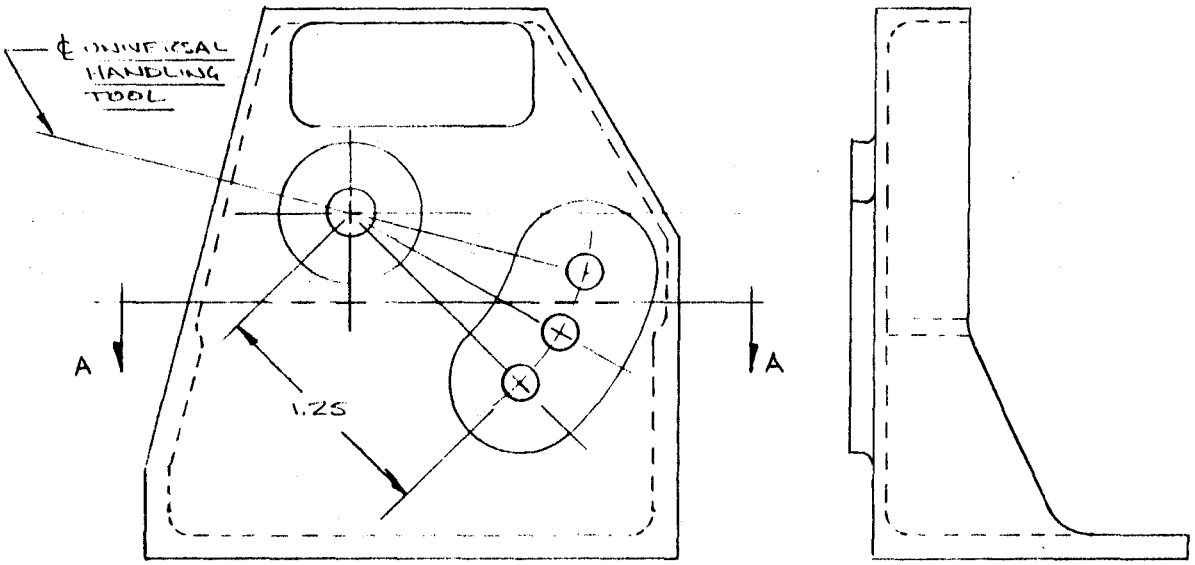
③ REDUCED $F_{ty}$ NEAR AREA OF WELD REF. PAGE 76

② REF. NO. 4, TABLE III, CASE 31

① REF. PAGE 72

FINAL ANALYSIS LRRR-300

BRACKET, HANDLE L.H. DWG. 2347240




SECTION A-A

LOADS & MOMENTS COND. 2

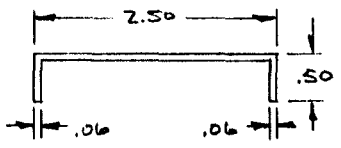
ASTRONAUT FORCE (ULT.) = 45 lbs

CONSERVATIVELY ASSUME THE HANDLE TRANSFERS NO LOAD TO THE RIGHT HAND BRACKET AND SECTION A-A RESISTS THE TOTAL TORQUE INDUCED BY 45 lb ASTRONAUT FORCE BEING APPLIED AT THE U.H.T. HANDLE.

TORQUE, $T = 27.12 (45) = 1220$ lbs

ASSUME THE TORQUE IS TAKEN OUT AS FLANGE SHEAR WITH NO HELP FROM THE WEB:

$$P_{FLANGE\ SHEAR} = \frac{1220}{2.44} + \frac{45}{2} = 523 \text{ lbs}$$



FINAL ANALYSIS LRRR-300

BRACKET, HANDLE L.H. DWG. 2347240

SECTION A-A (CONT'D)

SECTION PROPERTIES

$A_{FLANGE} = .06(.50) = .03$

STRESSES MAT'L: 6061-T651 $F_{tu} = 42$ KSI

$F_{su} = 27$ KSI $f_s = \frac{523}{.03} = 17.5$ KSI

$M.S. = \frac{F_{su}}{f_s} - 1 = +.54$

FINAL ANALYSIS LRRR-300

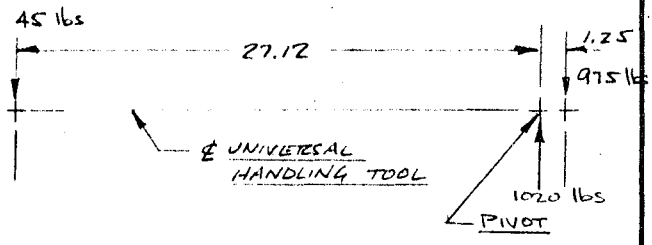
BRACKET, HANDLE L.H. DWG. 2347240

BEARING CHECK ADJUSTMENT PIN AGAINST BRACKET

BEARING LOADS (1) COND. 2

LOAD AT ADJUSTMENT HOLE

$$P_{br} = \frac{122.0}{1.25} = 975 \text{ lbs}$$




BEARING PROPERTIES

PIN DIA = .188

$t$ = .19

$A_{br} = Dt = .188(.19) = .0357$

BEARING STRESSES MAT'L: 6061-T651 $F_{tu}$ = 42 KSI

$F_{bry}$ = 50 KSI $\quad f_{br} = \frac{975}{.0357} = 27.3$ KSI

$$M.S. = \frac{F_{bry}}{(2)\ 1.5 f_{br}} - 1 = \underline{1.22}$$

(2) BEARING FACTOR

(1) REF. PAGE 68

FINAL ANALYSIS LRRR-300

ADJUSTMENT PIN - BRACKET, HANDLE L.H. & TOOL SOCKET

LOADS — COND. 2

(1) SHEAR LOAD = 975 lbs

PIN DESIGNATION

AN3 CRES BOLT

BOLT ALLOWABLES

SINGLE SHEAR LOAD = 2125 lbs

$$M.S. = \frac{2125}{975} - 1 = +1.18$$

PIVOT PIN

LOADS — COND. 2

(1) SHEAR LOAD = 975 + 45 = 1020 lbs

PIN DESIGNATION

AN4 CRES BOLT

BOLT ALLOWABLE

SINGLE SHEAR LOAD = 3680 lbs

$$M.S. = \frac{3680}{1020} - 1 = +2.61$$

(1) REF MIL-F 70

PREPARED BY JFC
CHECKED BY
REVISED BY

**ENGINEERING REPORT**
Bendix Aerospace Systems Division

DATE 12-17-70 PAGE 72
REPORT No. ATM-934
MODEL LRRR-300

FINAL ANALYSIS LRRR-300

HANDLE DWG. 2347239-1

SECTION E-E

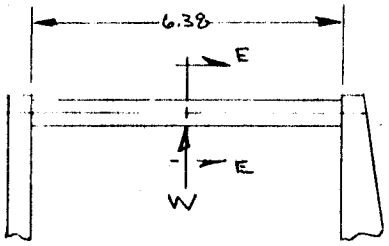
LOADS & MOMENTS COND. 3

$W = 2(100) = 200$ (1)

$M_{Z_{E-E}} = \frac{WL}{8} = \frac{200(6.38)}{8}$ (2)

$= 159.5$ IN-LBS

SHEAR $= \frac{W}{2} = 100$ LBS




SECTION PROPERTIES

$A = .50(1.25) - 1.062(.312) = .294$

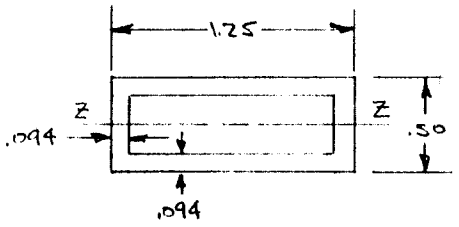
$I_Z = \frac{1.25(.50)^3}{12} - \frac{1.062(.312)^3}{12}$

$= .0103$

$I_{Z/C} = .0412$

$Q_Z = \frac{1.25(.25)^2}{2} - \frac{1.062(.156)^2}{2} = .0262$

$K_S = \frac{2Q_Z}{I_{Z/C}} = \frac{2(.0262)}{.0412} = 1.27$




STRESSES MAT'L: 6061-T6 AL. ALLOY $F_{tu} = 24$ KSI (3)

$F_b = 29.8$ KSI $\quad f_b = \frac{159.5}{.0412} = 3.87$ KSI $\quad K_b = .130$

$F_{S_0} = 15.3$ KSI $\quad f_S = \frac{100}{.294} = .34$ KSI $\quad K_S = .022$

$U = [K_b^2 + K_S^2]^{1/2} = .132$

$M.S. = \frac{1}{U} - 1 =$ AMPLE

(3) REDUCED ALLOWABLE DUE TO WELDING REF. PAGE 76
(2) REF No. 4, TABLE III, CASE 31
(1) WEIGHT OF LRRR 300 ASSUMED TO BE 100 LBS

FINAL ANALYSIS LRRR-300

TOOL SOCKET, ADJUSTABLE DWG. 2347242

SOCKET ANALYSIS

THE SOCKET CONFIGURATION IS IDENTICAL TO THE SOCKET USED ON LRRR. SINCE THE LOADS ARE THE SAME, THE ANALYSIS FOR THE SOCKET THAT IS INCLUDED IN REPORT ATM 871 COVERS THE SOCKET TO BE USED ON THE LRRR-300. THEREFORE, NO FURTHER ANALYSIS WAS DEEMED NECESSARY.

BEARING CHECK ADJUSTMENT PIN AGAINST TOOL SOCKET

BEARING LOAD

$P_{br}$ (1) = 975 lbs

BEARING PROPERTIES

PIN DIA = .188

$t$ = .12

$A_{br} = Dt = .188(.12) = .0236$

BEARING STRESSES MAT'L: 17-4 PH STAINLESS STEEL

$F_{tu}$ = 190 KSI

$F_{bry}$ = 255 KSI

$f_{br} = \frac{975}{.0236} = 41.3$ KSI

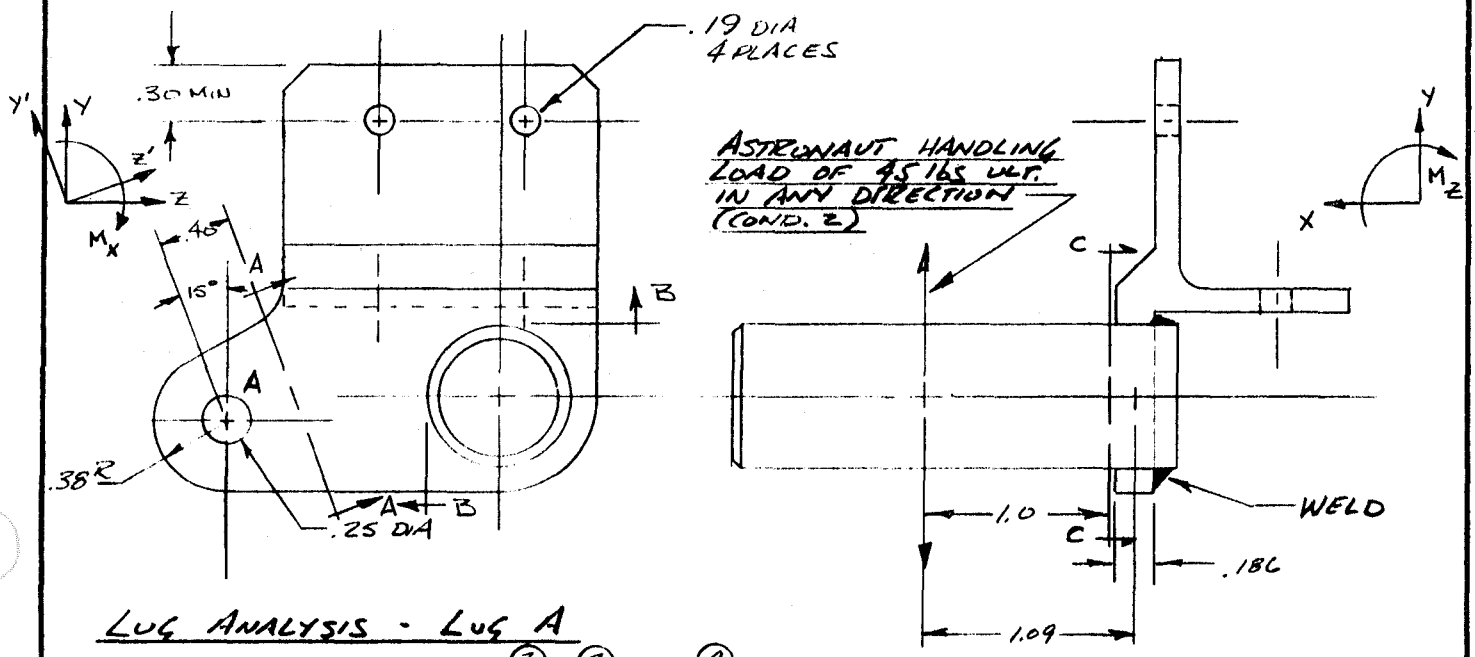
$M.S. = \frac{F_{bry}}{(2)\ 1.5 f_{br}} - 1 = \underline{+3.10}$

(2) BEARING FACTOR
(1) REF. PAGE 70

# FINAL ANALYSIS - LRRR-300

## BRACKET, FWD TIE DOWN - SMALL ARRAY DWG. 2947237

COND. 1




## LUG ANALYSIS - LUG A

Lug Load, $P_{LUG} = P_a = P_{tr} = 225$ lbs ③ ③ ④ COND. 1

### LUG PROPERTIES ①

$a = .38$ $a/D = 1.52$ $K_{br} = 1.08$ $\theta = 0°$ $R = .125$

$D = .25$ $t = .186$ $E = a - R = .255$ $R/E = .49$

$W = .76$ $W/D = 3.00$ $K_t = .47$ $K_1 = 1.085$ $\frac{A_{av}}{A_{br}} = \frac{K_1 E}{2R} = 1.105$

$A_{br} = Dt = .0465$ $A_t = (W-D)t = .093$ $K_{tru} = .53$

### LUG ALLOWABLES

MAT'L: AL. ALLOY 6061-T651 $F_{tu} = 42$ KSI

AS WELDED $F_{tu} = 24$ KSI (REF NO. 7, PAGE 78)

**TENSION**

$P_{tu} = K_t A_t F_{tu} = .47(.093)\,24000 = 1049$ lbs

$$M.S. = \frac{P_{tu}}{1.15\,P_a} - 1 = \underline{+3.05} \quad ②$$

**SHEAR BEARING**

$P_{bru} = K_{br} A_{br} F_{tu} = 1.08(.0465)\,24000 = 1205$ lbs

**TRANSVERSE**

$P_{tru} = K_{tr} A_{br} F_{tu} = .53(.0465)\,24000 = 591$ lbs

$$M.S. = \frac{P_{tru}}{1.15\,P_{tr}} - 1 = \underline{+1.28} \quad ②$$

② FITTING FACTOR
① REF NO. 3, SECTION 2.3
④ REF. PAGE 60
③ ACTING SEPARATELY

FINAL ANALYSIS LRRR-300

BRACKET, FWD TIE DOWN - SMALL ARRAY DWG. 2347237

SECTION A-A

(1) LOADS AND MOMENTS COND. 1

$P_{X_{BKT}} = 300$ lbs

$P_{Z_{BKT}} = 56$ lbs

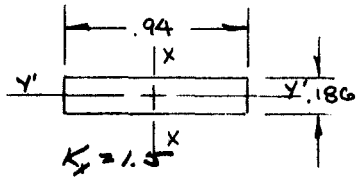
$SHEAR = \left[P_{X_{BKT}}^2 + (P_{Z_{BKT}} \sin 15°)^2\right]^{1/2} = 300$ lbs

$COMP = P_{Z_{BKT}} \cos 15° = 54.1$ lbs

$M_{y'_{A\text{-}A}} = .40\, P_{X_{BKT}} = 120$ IN-lbs

$M_{X_{A\text{-}A}} = .40\,(P_{Z_{BKT}} \sin 15°) = 5.8$ IN-lbs

SECTION PROPERTIES




$A = .186\,(.94) = .174$

$I_x = \frac{.186\,(.94)^3}{12} = .0129$ $\quad I_{x/c} = .0274$ $\quad K_y = 1.5$

$I_{y'} = \frac{.94\,(.186)^3}{12} = .0005$ $\quad I_{y'/c} = .0054$ $\quad K_{y'} = 1.5$

STRESSES MAT'L 6061-T651 AL. ALLOY $F_{tu} = 42$ KSI

(2) AS WELDED $F_{tu} = 24$ KSI $\quad F_{ty} = 17$ KSI

(3)

$F_{by'} = 1.45\, F_{tu} = 61$ KSI $\quad f_{by'} = \frac{120}{.0054} = 22.2$ KSI $\quad R_{by'} = .364$

$F_{bx} = 61$ KSI $\quad f_{bx} = \frac{5.8}{.0274} = .21$ KSI $\quad R_{bx} = .004$

$F_{cy} = 55\left(\frac{17}{33}\right) = 17$ KSI $\quad f_c = \frac{54.1}{.174} = .31$ KSI $\quad R_c = .018$

$F_s = \frac{24}{\sqrt{3}} = 13.8$ KSI $\quad f_s = \frac{300}{.174} = 1.73$ KSI $\quad R_s = .125$

$U = \left[(R_{by'} + R_{bx} + R_c)^2 + R_s^2\right]^{1/2} = .406$

$M.S. = \frac{1}{U} - 1 = \underline{+1.46}$

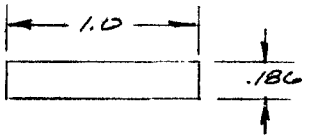
(3) REF. No. 3, PAGE 3.01-3
(2) REF. No. 7, PAGE 78
(1) REF. PAGE 64

FINAL ANALYSIS - LRRR-300

BRACKET, FWD TIE DOWN - SMALL ARRAY DWG. 2347237

SECTION B-B

CONSERVATIVELY ASSUME SECTION SHAPE & LOCATION AS SHOWN




LOADS & MOMENTS ON SECTION COND. 2

TENSION = 45 lbs

MOMENT = 45 (1.09) = 49 IN-lbs

SECTION PROPERTIES

$A = .186(1.00) = .186$

$I = \frac{1.00(.186)^3}{12} = .00053$

$I/c = .0057$

STRESSES MAT'L: AL. ALLOY 6061-T651 $F_{tu}$ = 42 KSI, $F_{ty}$ = 35 KSI

$f_b = \frac{49.0}{.0057} = 8600$ PSI

$f_t = \frac{45}{.186} = 242$ PSI

$f_b + f_t = 8892$ PSI

$F_{tu}$ OF AL. ALLOY (PARENT METAL) NEAR WELD = 24000 PSI (1)

$F_{ty}$ " " " " " " 17000 PSI

$$M.S. = \frac{F_{ty}}{f_b + f_t} - 1 = \underline{+.92}$$

PART WILL NOT YIELD UNDER ASTRONAUT HANDLING

(1) REF No. 7, PAGE 78, TABLE 69.35

FINAL ANALYSIS - LRRR-300

BRACKET, FWD TIE DOWN - SMALL ARRAY DWG 2347237

SECTION C-C - THRU HANDLE COND. 2

MOMENT = 1.0 (45.0) = 45.0 IN-LBS

SECTION PROPERTIES

OD = .75 A = .079 $I/c = \frac{.005}{.375} = .0133$
ID = .68 I = .005
t = .035 D/t = 21.4 $F_b/F_{tu} = 1.80$ (1)

STRESSES MAT'L: AL. ALLOY 6061-T651 $F_{tu}$ = 42 KSI
$F_{tu}$ IN WELD AREA = 24000 PSI (2) $F_{ty}$ = 35 KSI

$F_b = 1.8 F_{tu} = 43200$ PSI $f_b = \frac{45.0}{.0133} = 3380$ PSI $R_b = .078$

$F_{su} = 27000 \left(\frac{24}{42}\right) = 15300$ PSI $f_s = \frac{45.0}{.079} = 570$ PSI $R_s = .037$

$U = R_b + R_s = .086$

$M.S. = \frac{1}{U} - 1 =$ AMPLE

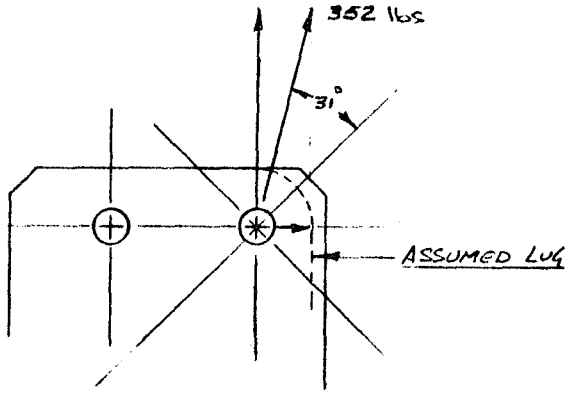
(2) REF. No. 7, PAGE 78
(1) REF. No. 3, PAGE 3.01-1

FINAL ANALYSIS LRRR-300

BRACKET, FWD TIE DOWN - SMALL ARRAY DWG. 2347237

TEAR OUT AT BOLT HOLE

ASSUME BOLT HOLE ACTS AS A LUG WITH 352 lbs APPLIED AS SHOWN




LUG LOADS

(1) $F_{BOLT} = 352$ lbs

$P_a = F_{BOLT} \cos 31° = 302$ lbs

$P_{tr} = F_{BOLT} \sin 31° = 181$ lbs

LUG PROPERTIES (2)

$D = .19$ $A_{br} = Dt = .0152$ $\theta = 45°$ USE $30°$

$t = .08$ $A_t = (w-D)t = .0344$

$a = .31$ $a/D = 1.63$ $K_{br} = 1.11$

$W = .62$ $W/D = 3.26$ $K_t = .69$

$R = .095$ $E = a - R = .215$ $R/E = .44$ $K_1 = 1.41$

$$\frac{A_{AV}}{A_{br}} = \frac{K_1 E}{2R} = \frac{1.41(.215)}{.19} = 1.59$$

LUG ALLOWABLES MAT'L: 6061-T651 AL. ALLOY $F_{tu} = 42$ KSI

AS WELDED $F_{tu} = 24$ KSI (3)

TENSION

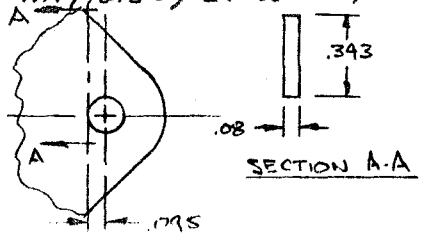
$P_{tu} = K_t A_t F_{tu} = .69(.0344)\,24000 = 570$ lbs

SHEAR BEARING

$P_{bru} = K_{br} A_{br} F_{tu} = 1.11(.0152)\,24000 = 405$ lbs $R_a = .745$

TRANSVERSE

$$P_{tr} = \frac{F_b I_{/c}}{l} = \frac{34800(.00156)}{.095} = 571 \text{ lbs}$$




$I_{/c} = \frac{.08(.343)^2}{6} = .00156$

$F_b = 1.45 F_{tu} = 34800$ PSI

$R_r = .316$

$I/I = [R_a^{1.6} + R_r^{1.6}]^{1/1.6} = .858$

$M.S. = \frac{1}{1.15\,U} - 1 = +.01$ (4)

(3) REF NO. 7, PAGE 18, PARA 6.4.5

(2) REF NO. 3, SECTION 23

(1) REF PAGE 79

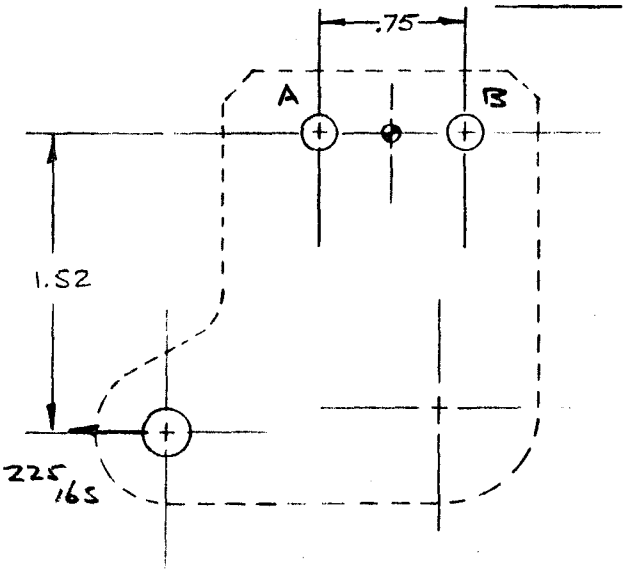
(4) FITTING FACTOR

# FINAL ANALYSIS - LRRR-300

## BOLT PATTERN ANALYSIS - FORWARD TIE DOWN BRACKET (2347237) TO SMALL ARRAY

### LOADS

COND. 1




(1) $P_{BRACKET\ LUG} = 225$ lbs

DIRECT FORCE ON BOLTS (A) & (B)

(2) $F = \frac{.75(225)}{2} = 84.5$ lbs

CONSTANT OF PROPORTIONALITY OF BOLT PATTERN, K:

(3) $K = \frac{1.52(169)}{2(.375)^2} = 914$

MOMENT FORCE ON BOLTS:

(3) $F_M = Kr = 914(.375)$
$= 342$ lbs

MAXIMUM FORCE ON BOLTS:

$F_{BOLT} = (F^2 + F_M^2)^{1/2} = 352$ lbs

### BOLT DESIGNATION

AN 3 CRES BOLT

### BOLT MARGIN OF SAFETY

SINGLE SHEAR STRENGTH = 2125 lbs

$M.S. = \frac{2125}{352} - 1 = +5.04$

(3) REF. No. 5, PAGE 139
(2) CONSERVATIVELY ASSUME BOLTS (A) & (B) CARRY 50% OF BRACKET LOAD.
(1) REF. PAGE 63

FINAL ANALYSIS LRRR-300

BRACKET, REAR TIE DOWN - SMALL ARRAY DWG. 2347238

LUG ANALYSIS COND. 1

ASSUMPTIONS:

1. SMALL ARRAY WEIGHT ≈ 30 lbs
2. BRACKET SEES NO LOAD IN THE X-DIRECTION
3. EQUAL LOAD DISTRIBUTION ON TIE DOWN BRACKETS & HINGES (Y & Z-DIRECTIONS)

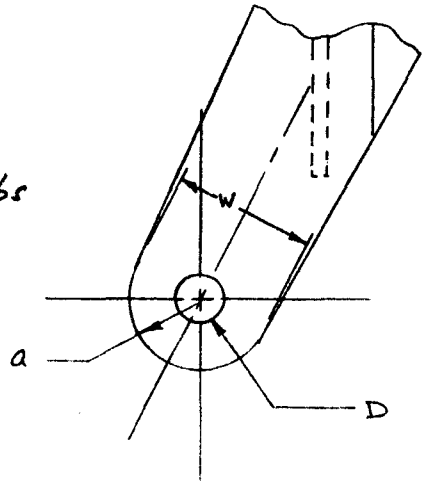
LUG LOADS

SMALL ARRAY FORCE AT 30 G'S

$P = 30(30) = 900$ lbs

BRACKET LOAD $= .25(900) = 225$ lbs

$P_{AXIAL}$ ③ $= P_{TRANSVERSE}$ ③ $= P_{BRACKET} = 225$ lbs




LUG PROPERTIES ①

| | | | |
|---|---|---|---|
| $D = .25$ | $a/D = 1.52$ | | |
| $t = .10$ | $W/D = 3.04$ | | |
| $a = .38$ | $A_{br} = Dt = .025$ | $K_{br} = 1.06$ | |
| $W = .76$ | $A_t = (W-D)t = .051$ | $K_t = .80$ | |
| $R = .125$ | $E = a - R = .255$ | $\Theta = 0°$ | |
| $R/E = .49$ | $K_1 = 1.09$ | $\frac{A_{AV}}{A_{br}} = \frac{K_1 E}{2R} = 1.09$ | $K_{tru} = .52$ |

ALLOWABLE LUG LOAD MAT'L: 6061-T651 AL. ALLOY $F_{tu} = 42$ KSI

TENSION

$P_{tu} = K_t A_t F_{tu} = .80(.051)\,42000 = 1710$ lbs

SHEAR-BEARING

$P_{bru} = K_{br} A_{br} F_{tu} = 1.06(.025)\,42000 = 1110$ lbs

$M.S. = \frac{P_{bru}}{1.15\,P_{BRACKET}}$ ② $- 1 = +3.29$

TRANSVERSE

$P_{tru} = K_{tru} A_{br} F_{tu} = .52(.025)\,42000 = 545$ lbs

$M.S. = \frac{P_{tru}}{1.15\,P_{BRACKET}}$ ② $- 1 = +1.10$

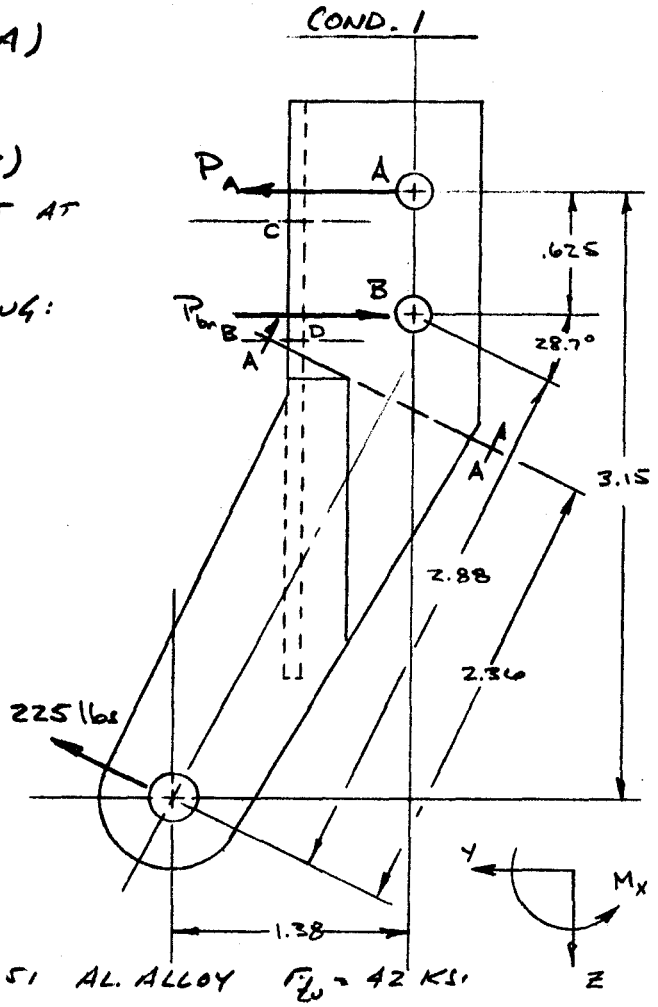
② FITTING FACTOR

① REF. NO. 3, SECTION 2.3 ③ ACTING SEPARATELY

FINAL ANALYSIS LRRR-300

BRACKET, REAR TIE DOWN - SMALL ARRAY DWG. 2347238

BEARING CHECK - AT BOLT HOLE (A)




ASSUMPTIONS:

1. BRACKET PIVOTS ABOUT BOLT (B)
(1) 2. BRACKET LUG LOAD TAKEN OUT AT BOLT (A)
3. BRACKET LOAD APPLIED AT LUG:
(2) $P_{BRACKET}$ = 225 lbs

REACTION AT (A)

$$P_A = \frac{2.88(225)}{.625} = 1040 \text{ lbs}$$

BEARING LOAD AT (B)

$$P_{br_B} = P_A + 225 \cos 28.7$$
$$= 1040 + 197 = 1237 \text{ lbs}$$

BEARING PROPERTIES

DIA = .188
$t$ = .10
$A_{br}$ = .0188

BEARING STRESS MAT'L: 6061-T651 AL. ALLOY $F_{tu}$ = 42 KSI

$F_{bru}$ = 67 KSI

$$f_{br} = \frac{1237}{.0188} = 65.8 \text{ KSI}$$

(3) $$M.S. = \frac{F_{bru}}{f_{br}} - 1 = \underline{+.01}$$

(3) NO BEARING FACTOR INCLUDED DUE TO CONSERVATIVE ASSUMPTIONS USED.
(2) REF. PAGE 80
(1) CONSERVATIVELY ASSUME NO HELP FROM BOLTS OF OTHER FLANGE.

FINAL ANALYSIS LRRR-300

BRACKET, REAR TIE DOWN - SMALL ARRAY DWG. 2347238

SECTION A-A (1)

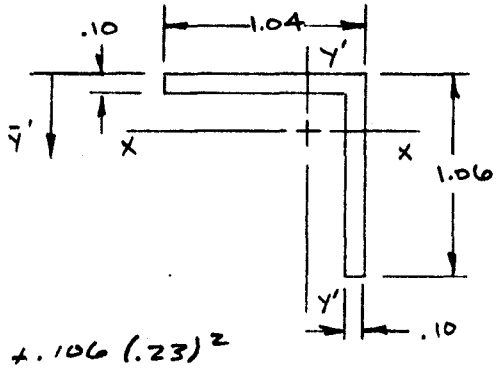
LOADS & MOMENTS (1) COND. 1

$P_{BRACKET} = 225$ lbs

B.M. $= 2.36(225) = 530$ IN-lbs

SHEAR $= P_{BRACKET} = 225$ lbs

SECTION PROPERTIES (2)




$A = .94(.10) + 1.06(.10) = .20$

$A\bar{Y}' = .094(.05) + .106(.53) = .0609$

$\bar{Y}' = \frac{A\bar{Y}'}{A} = .30$

$I_x = \frac{.94(.10)^3}{12} + .094(.25)^2 + \frac{.10(1.06)^3}{12} + .106(.23)^2$

$= .0215$ $\quad I_x/c = .0283$

$Q_x = \frac{.10(.76)^2}{2} = .0289$ $\quad K_x = \frac{2Q_x}{I_x/c} = 2.0$

STRESSES MAT'L: 6061-T651 AL. ALLOY $F_{tu} = 42$ KSI

$F_b = F_{tu} = 42$ KSI $\quad f_b = \frac{530}{.0283} = 18.7$ KSI $\quad R_b = .445$

$F_{su} = 27$ KSI $\quad f_s = \frac{225}{.20} = 1.13$ KSI $\quad R_s = .042$

$U = (R_b^2 + R_s^2)^{1/2} = .450$

$M.S. = \frac{1}{1.1} - 1 = +1.22$

(2) SHEAR CENTER OF SECTION CONSIDERED ZERO.

(1) REF PAGE 80

FINAL ANALYSIS LRRR-500

BOLT PATTERN - REAR TIE DOWN BRACKET TO SMALL ARRAY

ANALYSIS

LOAD (REF SKETCH PAGE 81) COND. 1

BOLT IN SHEAR:

CONSERVATIVELY ASSUME BOLT TAKES BEARING LOAD AT (B), $P_{br_B}$, IN SHEAR.

$$P_{SHEAR} = P_{br_B} = 1237 \text{ lbs} \quad (1)$$

BOLT IN TENSION:

ASSUME BRACKET PIVOTS ABOUT BOLT (C) AND THE REACTION OF THE LUG LOAD IS TAKEN OUT BY BOLT (D) AS TENSION. NO HELP IS ASSUMED FROM BOLTS AT (A) & (B). LUG LOAD APPLIED IN Y-DIRECTION.

$$P_{TENSION} = \frac{2.94(225)}{.625} = 1060 \text{ lbs}$$

BOLT PROPERTIES

AN3 CRES BOLT $F_{tu} = 125$ KSI

ALLOWABLE BOLT LOADS

SHEAR

$P_{ALLOWABLE\ SINGLE\ SHEAR} = 2125$ lbs $P_{SHEAR} = 1237$ lbs

M.S. = +.72

TENSION

$P_{ALLOWABLE\ TENSION} = 2210$ lbs $P_{TENSION} = 1060$ lbs

M.S. = +1.04

(1) REF PAGE 81

PREPARED BY JFC
CHECKED BY
REVISED BY

**ENGINEERING REPORT**
Bendix Aerospace Systems Division

DATE 12-10-70 PAGE 84
REPORT No. ATM-934
MODEL LRRR-300

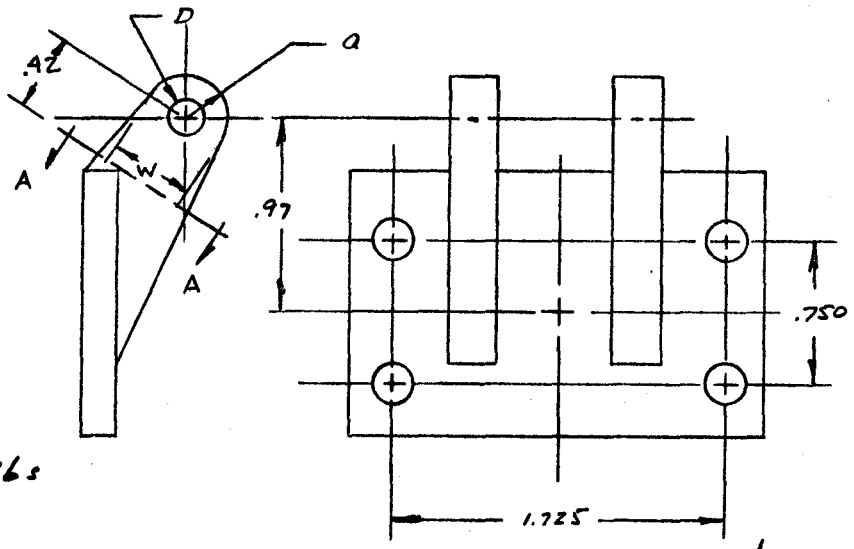
FINAL ANALYSIS LRRR-300

HINGE, BOTTOM (4) DWG 2347266

LUG ANALYSIS COND. 1

ASSUMPTIONS:

REF. PAGE 63




LUG LOADS

HINGE LOAD:

$P_{HINGE} = 22516s$

60-40 DISTRIBUTION

BETWEEN LUGS:

(3) $P_{a/LUG}$ & (3) $P_{br/LUG} = 13516s$

LUG PROPERTIES (1)

| | | | | | |
|---|---|---|---|---|---|
| $D = .19$ | $A_{br} = Dt = .0475$ | | $R = .095$ | | My |
| $t = .25$ | $A_t = (W-D)t = .0625$ | | $E = a - R = .125$ | $\theta = 0°$ | Z |
| $a = .22$ | $a/D = 1.16$ | $K_{br} = .94$ | $R/E = .76$ | $K_1 = 1.13$ | |
| $W = .44$ | $W/D = 2.32$ | $K_t = .62$ | $\frac{A_{AV}}{A_{br}} = \frac{K_1 E}{2R} = .744$ | $K_{tru} = .50$ | |

LUG ALLOWABLES MAT'L: 2024-T351 AL. ALLOY $F_{tu} = 62$ KSI

TENSION

$$P_{tu} = K_t A_t F_{tu} = .62(.0625)62000 = 2400 \text{ lbs}$$

$$M.S. = \frac{P_{tu}}{1.15 P_a} - 1 = \text{AMPLE} \quad (2)$$

SHEAR BEARING

$$P_{bru} = K_{br} A_{br} F_{tu} = .94(.0475)62000 = 2770 \text{ lbs}$$

TRANSVERSE

$$P_{tru} = K_{tru} A_{br} F_{tu} = .50(.0475)62000 = 1470 \text{ lbs}$$

$$M.S. = \frac{P_{tru}}{1.15 P_{tr}} - 1 = \text{AMPLE} \quad (2)$$

(4) THIS ANALYSIS COVERS THE TOP HINGE (2347265) ALSO.
(3) ACTING SEPARATELY
(2) FITTING FACTOR
(1) REF. NO. 3, SECTION 2.30

FINAL ANALYSIS LRRR-300

HINGE, BOTTOM

DWG. 2347266

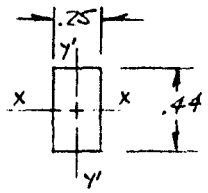
SECTION A-A

COND. 1

(1) LOADS AND MOMENTS

$P_{x_{HINGE}} = 300$ lbs

$M_{y'_{A-A}} = .42\, P_{x_{HINGE}} = 126$ IN-lbs




SECTION PROPERTIES

$A = .25(.44) = .11$

$I_{y'} = \frac{.44(.25)^3}{12} = .00057$ $\quad I_{y'/c} = .00456$ $\quad K_{y'} = 1.5$

$I_x = \frac{.25(.44)^3}{12} = .00177$ $\quad I_{x/c} = .00804$ $\quad K_x = 1.5$

STRESSES MAT'L: 2024-T351 AL. ALLOY $F_{tu} = 62$ KSI

$F_t = F_{tu} = 62$ KSI $\quad f_b = \frac{126}{.00456} = 27.6$ KSI $\quad R_b = .445$

$F_s = 37$ KSI $\quad f_s = \frac{300}{.11} = 2.75$ KSI $\quad R_s = .074$

$U = (R_b^2 + R_t^2)^{1/2} = .451$

$M.S. = \frac{1}{U} - 1 = \underline{\underline{+1.22}}$

(1) REF. PAGE 63

FINAL ANALYSIS LRRR-300

PIN, HINGE

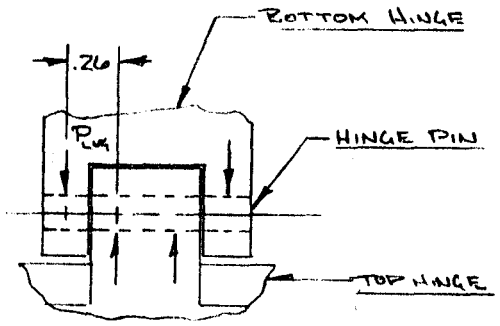
LOADS AND MOMENTS

COND. 1

① $P_{HINGE}$ = 225 lbs

$P_{LUG}$ = .60 $P_{HINGE}$ = 135 lbs

B.M. = .26 $P_{LUG}$ = 35.1 in·lbs




PIN PROPERTIES

DIA = .1875

A = .02761 I = .000061 $I/c$ = .00065 $D/t$ = 2.0

STRESSES MAT'L: AISI 304 STAINLESS STEEL $F_{tu}$ = 75 KSI

SHEAR FACE

$F_{su}$ = 40 KSI $f_s = \frac{135}{.02761} = 4.90$ KSI

$M.S. = \frac{F_{su}}{f_s} - 1 = \underline{+7.16}$

BENDING CHECK

$F_b$ = 124 KSI $f_b = \frac{35.1}{.00065} = 54$ KSI

$M.S. = \frac{F_{bu}}{\frac{1.15}{②} f_b} - 1 = \underline{+.99}$

② FITTING FACTOR

① REF. PAGE 63

FINAL ANALYSIS LRRR-300

BOLT PATTERN ANALYSIS - HINGE TO ARRAY (4)

LOADS

COND. 1

(1) HINGE LOAD = 300 lbs

DIRECT FORCE ON BOLTS:

$$F = \frac{300}{4} = 75 \text{ lbs}$$

CONSTANT OF PROPORTIONALITY OF BOLT PATTERN, K:

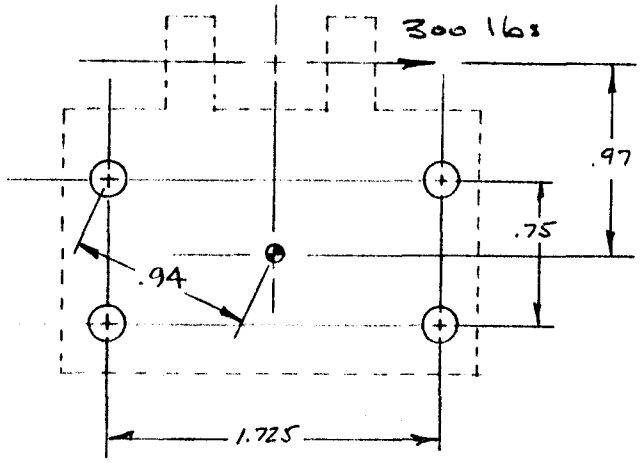
(2) $$K = \frac{.97(300)}{4(.94)^2} = 82.5$$

MOMENT FORCE ON BOLTS:

(2) $F_M = Kr = 82.5(.94) = 77.5$ lbs

MAXIMUM FORCE AT BOLTS:

(3) $F_{BOLT} = F + F_M = 152.5$ lbs




BOLT DESIGNATION

AN 3 CRES BOLT

ULT. TENSILE STRENGTH = 2210 lbs
YLD. " " = 1690 lbs
SINGLE SHEAR STRENGTH = 2125 lbs

BOLT MARGIN OF SAFETY

$$M.S. = \frac{2125}{152.5} - 1 = \text{AMPLE}$$

(4) ANALYSIS COVERS BOTH TOP & BOTTOM HINGES
(3) CONSERVATIVELY ASSUME LOADS ACTING IN LINE.
(2) REF. NO. 5, PAGE 239
(1) REF. PAGE 63

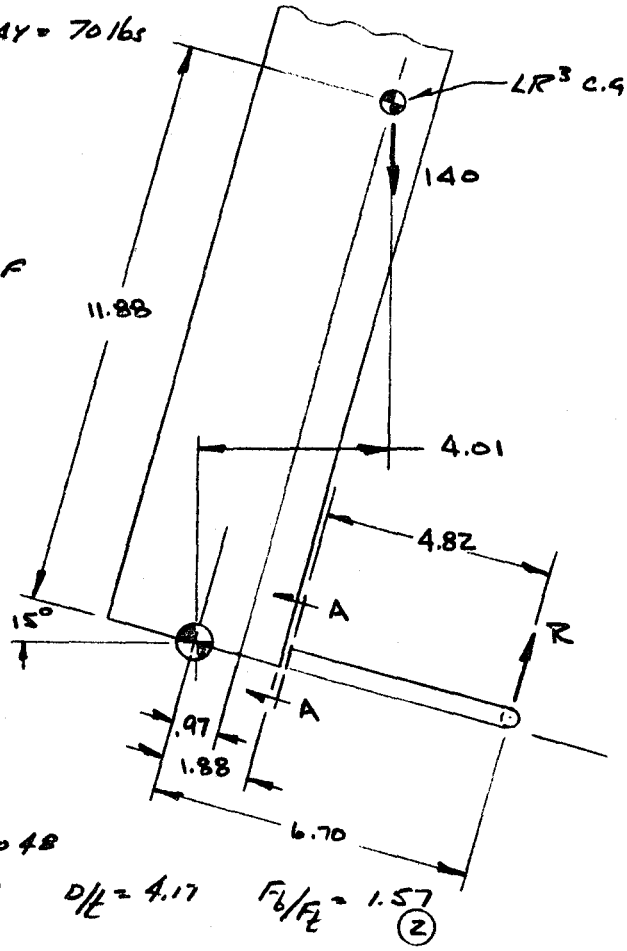
# FINAL ANALYSIS LRRR-300

## REAR SUPPORT ROD

DWG. 2347235

### ASSUMPTIONS:

1. WEIGHT OF LR$^3$ WITHOUT SMALL ARRAY = 70 lbs
2. 2G CONDITION ON 15° SLOPE
3. LR$^3$ PIVOTS ABOUT MIDPOINT OF BOTTOM RESTING PLATE
4. 60-40 LOAD DISTRIBUTION ON SUPPORT HOOP LEGS
5. AMBIENT LUNAR TEMP. = +250° F




### LOADS

$WT_{LR^3} = 2(70) = 140$ lbs

REACTION AT SUPPORT HOOP END, R:

$$R = \frac{140(4.01)}{6.70} = 84 \text{ lbs}$$

$.60\,R = 51.4$ lbs

MOMENT AT BASE OF LEG:

Moment = 4.82 (51.4) = 243 in-lbs

### SECTION PROPERTIES (SECTION A-A)

O.D. = .375 A = .0805 $I_c$ = .0048

I.D. = .195 I = .0009 t = .09 D/t = 4.17 $F_b/F_t$ = 1.57 (2)

### STRESSES

MAT'L: 2024 AL. ALLOY TUBING T-3 SPEC 7003/3
OD = .375 $t_{WALL}$ = .09

$F_{tu}$ = 64 KSI $F_{ty}$ = 42 KSI

$F_{ty_{ELEV.\ TEMP}}$ = .91 $F_{ty}$ = 38.2 KSI (1)

$F_{by} = 1.57\,F_{ty_{E.T.}} = 60.0$ KSI $\quad f_b = \frac{243}{.0048} = 50.6$ KSI $\quad R_b = .844$

$F_{sy} = \frac{F_{ty_{E.T.}}}{\sqrt{3}} = 22.0$ KSI $\quad f_s = \frac{.0514}{.0805} = .64$ KSI $\quad R_s = .029$

$$U = \left[R_b^2 + R_s^2\right]^{1/2} = .844$$

$$M.S. = \frac{1}{U} - 1 = \underline{+.18}$$

(2) REF. NO. 3, PAGE 3.01-1
(1) REF. NO. 6, FIGURE 3.2.3.1.1.

FINAL ANALYSIS LRRR-300

REAR SUPPORT ROD

DWG. 2347235

SUPPORT HOOP DEFLECTION ON 15° SLOPE

ASSUME SUPPORT HOOP LEG ACTS AS A SIMPLE CANTILEVER

(1) $\delta = \frac{Wl^3}{3EI}$

$= \frac{51.4(4.82)^3}{3(10.5\times10^6)(.0009)}$

$= .202$ IN. (EARTH CONDITIONS)

WHERE: $W = .60\,R = 51.4$ lbs

$l = 4.82$

$E = 10.5\times10^6$ PSI

$I = .0009$

$E_{\text{ELEV. TEMP}} = .97E = 10.2\times10^6$ PSI (2)

FOR LUNAR SURFACE CONDITIONS:

$W = \frac{51.4}{6} = 8.55$ lbs

$\delta = \frac{Wl^3}{3EI} = \frac{8.55(4.82)^3}{3(10.1\times10^6).0009} = .035$ IN

THE ABOVE DEFLECTIONS ASSUME A HARD SURFACE AND CONSIDERS NO SURFACE IMPRESSION. NO SUPPORT IS CONSIDERED FROM OTHER LEG.

(2) REF. No. 6, FIGURE 3.2.3.1.4.

(1) REF. No. 4, TABLE III CASE 1

FINAL ANALYSIS - LRRR-300

SUN COMPASS SPRING DWG. 2347269

SPRING PROPERTIES

SPRING MEAN DIA, D = .356
WIRE DIA., d = .048
E = $30 \times 10^6$
LENGTH OF ACTIVE WIRE, L = .672
NUMBER OF ACTIVE COILS, N = 13
MINIMUM TENSILE STRENGTH, $S_M$ = 262 KSI

MOMENT AT FINAL LOCATION = 1.5 IN-LB

TORQUE REQ'D TO DEFLECT SPRING ONE TURN:

(1) $M = \frac{E d^4 T}{10.8 N D} = \frac{30 \times 10^6 (.048)^4 1}{10.8 (13) .356} = 3.185$ IN-LBS

WIRE STRESS DUE TO 1.5 IN-LB TORQUE

(1) $S = \frac{32 M}{\pi d^3} = \frac{32 (1.5)}{\pi (.048)^3} = 141.2$ KSI

$M.S. = \frac{S_M}{S} - 1 = +.85$

TORQUE REQ'D FOR DEFLECTION OF 165°:

$3.185 \left( \frac{165}{360} \right) = 1.46$ IN-LBS

THIS FALLS WITHIN THE LIMITS SPECIFIED ON THE DRAWING.

(1) REF. NO. 10, PAGE 45

FINAL ANALYSIS LRRR-300

RIVET CONNECTION INVESTIGATION

THE FOLLOWING CONNECTIONS ARE ATTACHED WITH 4 .125 DIA RIVETS MADE OF 2117 AL. ALLOY:

| CONNECTION | MAX. CONNECTION LOAD |
|---|---|
| FRONT PIVOT BRACE (2347344) & FRONT PIVOT STRUCTURE CLEVIS (2347349) | 480 lbs (1) |
| FOOT (2347340) & FOOT BRACKET (2347338) | 211 lbs (2) |
| FOOT (2347340) & DIAGONAL SUPPORT BRACKET (2347336) | 224 lbs (2) |

ULTIMATE SHEAR ALLOWABLE FOR 2117-T4 AL. ALLOY:

$F_{SU} = 28$ KSI

CROSS-SECTIONAL AREA OF .125 DIA RIVET:

$A = .01227\ IN^2$

∴ MAX SINGLE SHEAR LOAD OF RIVET:

$$P_{SINGLE\ SHEAR} = A F_{SU}$$
$$= .01227 (28000) = 344\ lbs$$

SINCE EACH CONNECTION HAS 4 RIVETS AND THE MAXIMUM CONNECTION LOAD IS 480 lbs, ALL CONNECTIONS HAVE AMPLE STRENGTH.

(2) REF. PAGE 37
(1) REF. PAGE 57

FINAL ANALYSIS LRRR-300

SLOTTED SPRING PIN INVESTIGATION

THE FOLLOWING CONNECTIONS ARE ATTACHED WITH AN NAS 561-6 SLOTTED SPRING PIN

| CONNECTION | MAX. CONNECTION LOAD |
|---|---|
| LEG & FOOT ASSY (2347346) | 211 lbs (1) |
| DIAGONAL SUPPORT ASSY (2347345) | 224 lbs (1) |
| DIAGONAL SUPPORT TUBE (2347345-1) & REAR SUPPORT BRACKET (2347348) | 224 lbs (1) |

ALLOWABLE DOUBLE SHEAR LOAD OF AN NAS 561-6 SLOTTED SPRING PIN:

$$P_{\text{DOUBLE SHEAR}} = 4400 \text{ lbs}$$

∴ THE ABOVE CONNECTIONS HAVE AMPLE STRENGTH

(1) REF. PAGE 37